Foundations of Informing Science: 1999-2008

Edited by
T. Grandon Gill
Eli Cohen

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Table of Contents

PART I OVERVIEW

Chapter 1 Introduction to the Foundations of Informing Science
T. Grandon Gill and Eli Cohen 1

Chapter 2 Reconceptualizing Information Systems as a Field of the Discipline Informing Science: From Ugly Duckling to Swan
Eli Cohen 7

Chapter 3 Informing Science at a Crossroads: The Role of the Client
T. Grandon Gill and Anol Bhattacherje 21

PART II ELEMENTS OF INFORMING SCIENCE

Chapter 4 Informing Systems for Operations: A Teleological View
Zbigniew J. Gackowski 57

Chapter 5 Expanding the Concept of Usability
Alex Koohang 113

Chapter 6 Information and Informing Science
Karl T. Knox 135

Chapter 7 Task Complexity and Informing Science: A Synthesis
T. Grandon Gill and Richard C. Hicks 159

Chapter 8 Utility and Informing
T. Grandon Gill 197

Chapter 9 Informing Resonance: Beyond Rigor and Relevance
T. Grandon Gill 239

PART III PERSPECTIVES ON INFORMING SCIENCE

Chapter 10 Informing for Operations: The First Principia
Zbigniew J. Gackowski 287

Chapter 11 Informing Processes, Risks, Evaluation of the Risk of Misinforming
Dimitar Christozov, Stefanka Chukova & Plamen Mateev 323

Chapter 12 The Rugged Fitness Landscape and Informing Science Research
T. Grandon Gill 357

Chapter 13 Use and Redesign of Informing Systems: Lessons to Learn from Philosophizing and Practicing
Hans-Erik Nissen 411

Chapter 14 Inquiry into Informing Systems: Critical Systemic Thinking in Practice
Peter M. Bednar and Christine Welch 459

PART IV APPLICATIONS OF INFORMING SYSTEMS

Chapter 15 An Information System for a Bauxite Mine
J.E. Everett 503

Chapter 16 Information Politics and Information Culture: A Case Study
Bob Travica 521

Chapter 17 Informing Citizens in a Highly Restrictive Environment Using Low-Budget Multimedia Communications: A Serbian Case Study
Aleksandar Spasic and Miloje Nesic 577

Chapter 18 Cyberdating: (Dis)information and (Dis)trust in Online Interaction
Xin-An Lu and Hong Wang 619

Chapter 19 Web ACE – A Study in Reciprocal Informing
Iwona Miliszewska and Grace Tan 643

Chapter 20 **The Role of Informing Science in Establishing Research Context: An Integrated Model of Collaborative Knowledge Building Process**
Gurparkash Singh, Louise Hawkins, & Greg Whymark 661

PART V **NEW DIRECTIONS FOR INFORMING SCIENCE RESEARCH**

Chapter 21 **The Poverty of Empiricism**
Jens Mende 709

Chapter 22 **Routine versus Non-routine Informing: Reflections on What I Have Learned**
T. Grandon Gill 739

Chapter 23 **A Philosophy of Informing Science**
Eli Cohen..767

INDEX

Gill, T. G. & Cohen, E. (Eds.). (2009)
Foundations of Informing Science: 1999-2008
Santa Rosa, California: Informing Science Press (pp. 1-6)

PART I: OVERVIEW

Chapter 1

Introduction to the Foundations of Informing Science

T. Grandon Gill and Eli Cohen

Introduction

The transdiscipline Informing Science was first theorized just a decade ago. And what is this book series entitled *Foundations of Informing Science* all about? This is not a simple question and has no a simple answer.

Foundation. First, what do we mean by Foundation? Eli's initial thoughts on the meaning of foundation were that of a building's foundation. Buildings require a solid *foundation* to support additional construction upon these early emplacements. Eli envisioned a book in which colleagues would build upon the ideas in his seminal paper (presented here as Chapter 2). The problem was that his colleagues had ideas different from his. We explore this thread more in the section on *wise men*.

In contrast, Grandon was thinking more along the lines of "developing a field". To make the field fertile requires the addition of "organic fertilizer" and that Eli's seminal paper had a bit of it in it. (Actually, Grandon didn't say that, but Eli is sure that he thought it. After all, why else would he and Anol Bhattacherjee write their paper, adapted here as Chapter 3, in which they so elegantly expand and improve the initial concepts Eli's paper put forth.)

In the end, we agreed upon a definition of foundation as an organization to support an ideal, such as the National Science Foundation as a funding source for science innovation. The job of this book and the other activities of the Informing Science Institute (ISI) is to encourage ourselves and others to think more clearly and more deeply on what is Informing Science.

Informing Science Institute. The Informing Science Institute is not a traditional foundation. It does not enjoy an endowment of funds to help grow the thinking on informing science. Instead it sponsors and shepherds journals, books, and conferences that have this purpose. The Informing Science Institute is also a bit of any oddity in that it shies away from commercialism. It endeavors to be truly scientific. As an organization, it is guided by two principles: setting knowledge free by making all of its publication available free of charge online, and embracing mentorship, that is, colleagues helping colleagues learn how to improve.

Since the first issue of the journal *Informing Science: The International Journal of an Emerging Transdiscipline (InformSciJ)* in 1997 and the publication of the article that introduced the field to the outside world in 1999, the *Informing Science Institute (ISI)* has launched seven additional journals, published over two dozen books and managed two annual international conferences. The ISI's membership has grown to over 300 dues-paying scholars representing dozens of countries that span the entire globe and nearly as many client disciplines, drawn together by the common need to better understand the processes of informing. Together with non-member contributors and readers, ISI impacts thousands of colleagues. This is not a huge number, but the number is growing.

There is another meaning for foundation. We definitely were not thinking about foundation as in cosmetics, something to hide imperfections! As you read the chapters in this book, you may be struck by the degree of criticism of one another (and particularly of Eli's seminal work).

Emperor's Illusionary Clothing. There is a children's story (or metaphor) of an emperor whose arrogance led him to strut around wearing imaginary clothing. This warning against the dangers of academic arrogance can be seen in several chapters that caution the field of Management Information System on its need to reform.

But the same warning holds true for Informing Science. For this reason, you will see in this book a variety of definitions for Informing Science that contrast one to the other. Hopefully Informing Science in this series of books will remain humble enough not to recognize that theory without action is all in your head.

Wise Men. This book is a collaboration of many, many authors, each of whom has a slightly different concept of Informing Science. The last chapter uses the metaphor of the wise men in search of the truth about an elephant. Each wise man understands the elephant differently, each with complete confidence, but with only partial truth. The same is true of all complex phenomena, including Informing Science. As biological creatures, we wise men are limited by our own biases and limitations. You will see in the various chapters these various views and perspectives. All these are true, but no single view can provide the whole truth.

How the Chapters Were Selected and Developed

Consequently it is not our intent to define clear boundaries to what *is* and what *is not* informing science; such an assertion of authority is dangerous as it inhibits debate and learning. For this reason, we wanted to be sure that members of the informing science community had a significant say in what the series contained. Thus, we developed a call for chapters that provided for selection in three ways:

1. We each separately nominated a number of chapters
2. We solicited nominations from ISI members, including self-nominations
3. Researchers could propose to write a chapter, with inclusion in the book being conditional upon peer review and acceptance by one of the ISI family of journals

With respect to the first of these, one of our highest priorities was ensuring that the breadth of activities in the field was well represented. For the last two, both of us assessed the nominated article or proposal for relevance—with more than a few fine manuscripts being eliminated because we could not figure out how they related to informing.

After the initial list of possible chapters was established, we engaged in a process of mutual mentorship. Every author of a chapter included in the book was expected to review two chapters and provide constructive feedback as to how it could be improved. Since all the chapters making it to this stage had been peer reviewed prior to review by other authors, we made no attempt to assign chapters based upon a particular author's expertise or interests. To the contrary, since the entire purpose of the book was built around the notion of communicating with diverse client disciplines, we were eager to ensure that a reader did not have to be an expert in a particular field in order to get a reasonable sense of what was being communicated. For the purposes of this collection, a chapter's potential to inform a diverse audience was deemed even more important than the degree to which it breaks new research ground.

After the authors reviewed each other's work, for each chapter we synthesized the comments and proposed a series of changes that could—and in some cases—had to be made. The chapters were then sent back for revision, after which they were returned to us. In our capacity as editors, we then made an attempt to identify sections that we felt need to be clarified and, in some cases, actually did some rewriting contingent upon author approval. Authors then performed the final round of revision.

Organization

Once the initial set of chapters was nominated, we came up with a tentative organization for the book that, somewhat revised, defined the five parts of the current book. As the size of the book became clear, the decision to publish it in two volumes was made. In this section, we describe the content and objectives of each section.

Part I: Overview

The goal of Part I is to provide a context for understanding how informing science has evolved. In addition to this introduction, it includes Eli Cohen's seminal article "Reconceptualizing Information Systems as a Field of the Discipline Informing Science: From Ugly Duckling to Swan" that defined the transdiscipline and the Gill & Bhattacherjee "Informing Science at a Crossroads" article that was the direct inspiration for this book. Both chapters provide an introduction to informing systems and consider the role that informing science research can play. Because these chapters were included specifically for their influence on the field and on this book, we keep them close to their original form.

Part II: Elements of Informing Systems

In Part II, we introduce some of the core concepts associated with informing systems. In Chapter 4, Zbigniew Gackowski presents a general framework that describes routine informing for operations. In Chapter 5, Alex Koohang considers usability as a construct and presents empirical findings. In Chapter 6, Karl Knox explores alternative perspectives on information. In Chapter 7, Grandon Gill and Richard Hicks examine the concept of task complexity. The complexity theme continues in Grandon Gill's Chapter 8; it examines the economic concept of utility and explores how complexity impacts it. Chapter 9 introduces the concept of informing resonance.

Part III: Perspectives on Informing Science

Part III was organized to consider how different disciplines contribute to our understanding of informing. It begins with Chapter 10, in which Zbigniew Gackowski presents a set of general principles that apply to informing for operations. In Chapter 11, Dimitar Christozov, Stefanka Chukova and Plamen Mateev offer a mathematical analysis that considers the value of information and misinformation. In Chapter 12, Grandon Gill adapts the concept of a rugged fitness landscape, introduced in evolution biology, to informing and informing research. In Chapter 13, Hans-Erik Nissen explores how philosophy can contribute to our understanding of informing and informing system design. This theme is continued in Chapter 14 where Peter Bednar and Christine Welch consider how informing systems are constructed through a double helix model of adaption and reflection.

Part IV: Examples of Informing Systems

Part IV presents a series of case examples intended to demonstrate the range of applicability of informing science concepts. It begins with Chapter 15 where Jim Everett studies a routine informing system that was developed to improve the efficiency of bauxite mining. In Chapter 16, Bob Travica presents a sociological case study of a Canadian folk festival pavilion that initiated a major change in its informing patterns. In Chapter 17, Aleksandar Spasic and Miloje Nesic present a longitudinal study that examines the adaptations that took place as news organizations in Serbia attempted to circumvent the repressive regime in power at the time. In Chapter 18, Xin-An Lu and Hong Wang consider the processes of informing, misinforming and disinforming that take place in the world of Chinese cyberdating. In Chapter 20, Iwona Miliszewska and Grace Tan present a case study describing the informing patterns that occurred as students designed and then developed a web-based system for use by their teachers.

Part V: Future Directions for Informing Science Research

Part V includes chapters intended to synthesize the earlier chapters in the book and offer new directions. Chapter 21, 'The Poverty of Empiricism" was written by Jens Mende and represents an exception to the process of review and revision mentioned earlier. Shortly after his *InformSciJ* article of the same title was nominated for inclusion in the collection, he was killed during a home invasion in his native country of South Africa. Rather than attempting to revise his chapter or exclude it, we chose simply to reformat the original article and leave it otherwise unchanged.

In Chapter 22, Grandon Gill synthesizes the chapters included in Parts I through IV using a routine to non-routine continuum, subsequently used to order the chapters in each section. In Chapter 23, we return to Eli Cohen who (at the insistence of his co-editor) revisited his original definition of the field (Chapter 2) and offers his own insights into directions that the field may choose to take.

Conclusions

Informing science is a field that is rapidly evolving. It is our hope that this book will advance the transdiscipline both by offering the readers new ideas and by helping them visualize how they might better present their own research as contributions to informing science. We hope this collection will continue to grow with new volumes being published in the future, as exemplary manuscripts continue to be submitted to our journals and conferences, and as the informing science field continues to grow in stature, influence, and impact.

As editors of this book, we have learned a great deal about Informing Science from the contributors and each other. Let us leave you with a concept that is new to us: simplexity. It is an emerging theory that simply put simple things can best be understood as complex and complex things as simple. As you read the rest of the book, you too may become a proponent of simplexity theory.

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Chapter 2

Reconceptualizing Information Systems as a Field of the Discipline Informing Science: From Ugly Duckling to Swan[1]

Eli Cohen

Hans Christian Anderson wrote a tale in which all the young ducks made fun of another. They made the duckling feel inadequate because he was different. One day a swan, the most beautiful of the fowl, declared that the youngster was in fact a young swan and a fine one at that.

Abstract

The field of Information Systems (IS) has been attacked for its lack of tradition and focus. This paper suggests that the criticisms are based on the misunderstandings of the nature of Information Systems, both inside and outside the field. The paper begins by extending the fragmentation problem seen by Information Systems to the hierarchical model for knowledge expounded by the universities. It then examines the limitations of existing frameworks for defining IS, and introduces an evolutionary approach. This paper reconceptualizes Information Systems and demonstrates that it has evolved to be part of an emerging discipline of fields, Informing Science.

Keywords: evolution, informing science, history, information systems, framework, philosophy

The Problem with Information Systems

The maturing field of Information Systems (IS) is experiencing growing pains. It is not well recognized. Its research is fragmented, and its educational organization is not only fragmented, but competes with topics taught by other fields.

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1 Originally published in the Journal of Computing and Information Technology. 7 (3) 1999, 213-219

IS is not well differentiated from Applied Computer Science

As recently as January of 1998, the national publication *Netscape Enterprise Developer* published an article that demonstrates how misunderstood IS is, even among computing literati. The article "Ready to get your degree in IS?" decried the lack of business background among the graduates of computer science programs, apparently unaware of the 250 or so IS programs in the US alone. ("Ready to get your degree in IS?" 1998)

IS seems fragmented

A strong argument has been made that the both the research and the teaching of IS is anything but unified. In their review of research, Swanson and Ramiller (1993) write that they found fragmentation and pockets of inquiry in their review of IS research.

Similarly, IS '97, the undergraduate curriculum model for IS majors endorsed by three major professional organizations, includes a number of alternative paths that can be used to create majors that have little in common. (Davis et al., 1997)

Is IS so broad that no common research or learning agenda applies, or, as the critics of IS charge, is this a sign of lack of focus? Or, is this fragmentation a sign, as this paper suggests, that IS has been misconceptualized?

IS topics are taught throughout the campus

Nunnamaker (1996) and Cohen (1997) found that those topics that IS thinks of as its own (and that are found in its model curricula) are currently being taught in a large variety of fields, such as computer science, engineering, library science, social work, technology, education, communications, journalism, and design. Also the emphasis of what is taught as IS varies from campus to campus, and from country to country. Likewise, the IS program is variously housed as part of a school of business, liberal arts, engineering, or informatics.

Methods to define IS

To understand how IS has reached its current state of disarray, we need to examine how, in the past, IS determined what areas of knowledge it includes. Primarily, two methods have been used: one based on the other fields IS references and one based on definition. This paper introduces a third method, evolution.

1. Reference disciplines

The first method determines which knowledge is and is not IS by the fields it references. Kroenke (1984), Ahituv and Neumann (1990), and Laudon and Laudon (1996), among many others, have used this approach to define the field and use frameworks that are quite similar to one another. For example, Sprague (1980) argues that IS is derived from computer science, management sciences, organizational behavior, behavioral science, management accounting, economics, and library science. They all agree that the field of IS exists at the intersection of three sets of fields: business (management, inexact science), computing (technology), and systems (organization, exact science).

King argues that the appearance of the term "reference disciplines" in IS discourse reflects that the area of IS still lacks a "solid intellectual center" and the best way to address this issue is to "take the bull by the horn." But reference disciplines are critical for an evolving field for three reasons, as King explains. First, reference disciplines are a well-established source of intellectual capital; second, they provide the IS community with an "appeal to authority"; and finally, reference disciplines are an excellent way for identifying pockets of research that are uncharted. "Discipline is important for us, and obtaining it by reference is a perfectly sensible way for us to proceed, despite the inherently marginalizing consequence of our dependence on 'outside' versus 'inside' disciplinary traditions." (King, 1993)

Swanson and Ramiller (1993) wrote in their review of research of fragmentation and pockets of inquiry in three disparate fields: technical, humanistic, and business and economic. If this is the case, IS incorporates the union of three separate fields and is not at their intersection. Which of these fields is the true IS?

Even worse, Evaristo and Karahanna (1997) note that IS research as conducted in North America is qualitatively different from IS research conducted in Europe, both in focus and in epistemology. Where is the true IS research conducted?

Therefore, as King points out, information systems, as currently conceptualized, is probably not even a field, "but rather an intellectual convocation that arose from the confluence of interests among individuals from many fields who continue to pledge allegiance to those fields through useful ties of various kinds." (King, 1993)

2. Definition based

A definition based approach to determining what is IS uses words to describe its boundaries. Two definition-based methods have been used to define IS. One defines current IS by classifying the methods and topics have been studied in the past. The second approach is teleological, defining IS by the functions it provides its clientele.

Classification definition. Barki, Rivard, Talbot (1988, 1993) took the approach that IS is what IS does and set out to define the field by classifying its research. Other researchers also have taken this approach. Defining a discipline through a keyword classification scheme of research is like driving while looking through the rear-view mirror. It has a number of limitations:

- It is descriptive, not proscriptive,
- It is static, unresponsive to changes in the field and environment,
- The classification itself has cultural bias built-in, and
- The classification scheme is at best arbitrary.

Functional definition. In contrast to the classification definition, the functional definition is more dynamic and open to change. One of the earliest and most influential attempts to do this was by Mason and Mitroff (1973). They used an expanded sentence definition to provide boundaries of what is and what is not IS research. More specifically, they delineated IS as that field which assists "a **person** … with a certain **psychological type** with a **problem** within … an **organizational context** …by providing **evidence** …using a selected **mode of presentation**." The full model expands on the meanings of the various emphasized words of this word definition of the field. Note that the technical fields often associated with IS are not explicitly stated in this model.

Cohen (1983) expanded the work of Mason and Mitroff and others by conceptualizing IS through a meta-model derived from information theory. This simple three-component model provides a great deal of explanatory power. He applied a metasystem framework that defined IS on three levels: an Information-Using Environment, a Development Environment, and a Management Environment. This framework and the one above will be used later in this paper.

3. Evolution

This paper suggest evolution as a third approach to defining what areas of knowledge are IS. The evolutionary approach to IS examines the origins of the field. This approach is quite useful in understanding the current lack of consensus. It also points out connections to reference fields, both past and current.

Clearly, fifty years ago there were no individuals who professed IS, either as academics or as professionals. The profession of IS came into being through the evolution of other, precursor, occupations. The question is what were the precursor occupations that evolved into the IS profession?

One such occupation is the efficiency expert. The profession of efficiency expert came into existence to meet the needs of managers wishing to optimize the assembly line. It drew from fields as diverse as psychology and operations management. The occupation of systems analysis grew out of this line of thinking and working.

Office systems and most recently end-user computing, both of which IS considers as part of its realm, developed from the profession of secretary. (Regan, 1994)

Another precursor occupation is the accounting machine operator. The oldest organizations that include IS professionals, such as ACM and IACIS, drew membership from these workers. They operated the machines and provided much of the earliest programming. Both computer operation and programming are rooted in this profession.

Clearly, the profession of IS did not evolve from any one occupation. This explains why a variety of fields, such as accountancy and computer science, view IS as a part of their manifest destiny. The separate and sdisparate parent occupations of IS led to the misunderstanding of what IS is, both inside and outside the field.

A New Conceptualization of IS

This paper proposes a new conceptualization of IS along the lines of Mason and Mitroff (1973) and Cohen (1983). At its heart is a functional definition of those areas of knowledge which are IS.

> *Information Systems is the field of inquiry that attempts to provide the business client with information in a form, format, and schedule that maximizes its effectiveness.*

To understand what is information for a client, one must understand the client's task. To maximize the form, format, and schedule, one must understand not only the task, but also the client's psychology. This definition implicitly links IS to all its reference disciplines in an organized, consistent way. This definition includes almost, if not all, of the research that is currently published in IS journals.

Beyond Information Systems

Let us expand the definition above by removing the restriction that the client must be business related. This provides a definition for a number of disparate fields that share some common goals. We will call these fields collectively the discipline of Informing Science.

> *The fields that comprise the discipline of Informing Science provide their clientele with information in a form, format, and schedule that maximizes its effectiveness.*

The term Informing Science applies to disparate fields that share the common goal of **providing** a **client** with **information** in a form, format, and schedule that maximizes its effectiveness. The definition points to three interrelated components: the client (who has a task to perform that requires information for its completion), the delivery system (for providing information), and the informing environment that creates information to aid the clients complete their tasks. Table 1 lists some of the disciplines that comprise Informing Science. These are the very same fields that teach core IS topics, as noted in Nunnamaker (1996) and Cohen (1997).

Merely changing one term shows linkages between IS and a host of other fields. This paper refers to these fields collectively as the discipline of Informing Science. The definition also provides explanatory power over why non-IS disciplines teach courses on topics that IS claims for its own. While IS focuses on providing managers and other business clients with information, other fields define their clientele differently. For example, the clientele for education includes students. The information needs of students and of managers are not the same, but the task of providing information so as to make it useful for these two constituencies has a great deal of overlap.

Table 1. Examples of Informing Science Disciplines and their Clients

Informing Discipline	Client to be Informed
Information Systems	Workers in a Firm, Managers
Information Science	Library patron
Journalism	Reader/Viewer/Listener
Education	Learner
Public Relations	Public
Secretarial/Office Systems	Office Workers

The Informing Science Framework

Let us now expand the word definition to form a framework, shown in Figure 1. Readers will note that this framework contains elements derived from others' models. Combined, these elements form a powerful yet simple framework for the study of Information Systems and all of her sister disciplines; it provides a perspective on the field of IS.

The first of the works from which the Informing Science framework is derived is Shannon and Weaver's model of the communication process (Shannon, 1949). At its core, the model proposes understanding communications through its impact on five fundamental elements: the sender, the receiver, the medium, encoder, and decoder. Shannon and Weaver define information as a reduction in uncertainty. In this model, information can be said to be transmitted (and received) only if the receiver has reduced entropy. That is, information is defined in terms of the receiver's level of uncertainty. In the field of Information Systems, we would say information is defined as that which reduces risk for the decision-maker.

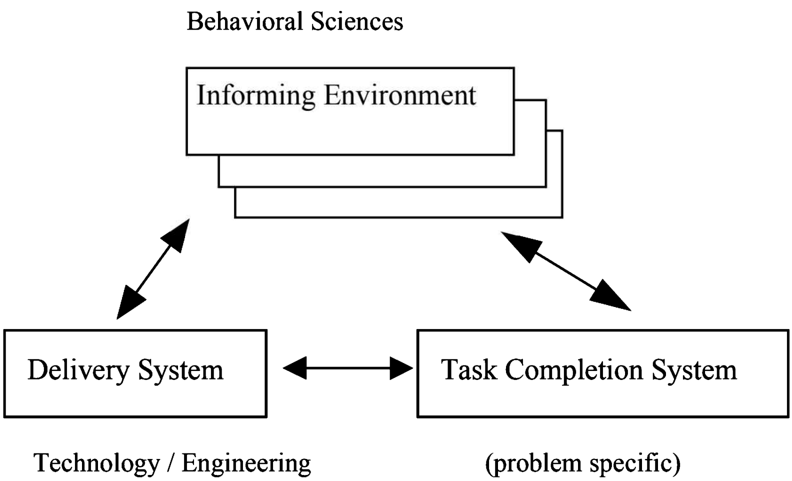

Figure 1. The Informing Science Framework

A second conceptual development from which the Informing Science framework is derived is that of the "meta-approach" to modeling. The meta-systems approach applies set-theory-like thinking to the analysis of systems. The obscurity of this useful approach has limited its use by researchers. To make the approach more accessible here, let us consider the simple example of applying meta-system analysis to building houses. At the most concrete level (no pun intended), we think about the individual house. The next higher level of abstraction considers all houses that follow one set of blue prints. A third, more abstract level considers the realm of the maker of blueprints, the architect. The architect creates plans, the builder constructs from architect-provided plans, and the house is an instance of the application of such plans. For Informing Science, we use three similar levels of abstraction: the implemented system, plans for implementation, and the creation of plans. (The "houses" we are building are systems to inform our clients. We are creating environments that promote informing.)

A third and final framework from which the Informing Science framework is derived is Leavitt's (1965) Change-Equilibrium Model. Leavitt writes that to understand organizational change, we must consider four distinct elements as inter-related: the task, technology, structure, and people. The key points here are that the components are interrelated, so a change in one affects all the others, and that the task, the technology, and other key components comprise the model.

Putting it together: The Informing Science Framework

The framework has three components: the informing environment, the delivery system, and the task-completion system.

Informing Environment. The informing environment is analogous to the sender and encoder in the communication model. Unlike the communication model, the Informing Science Framework considers the informing environment at three levels of abstraction. These three levels are (1) the instance (using a system that is in place), (2) the creation of new instances of informing (to the organization or any of its components), and, at the highest level, (3) the creation of new designs for informing.

An academic example of these three levels is as follows: (1) teaching a course someone else has designed, (2) designing a course that will be taught by others, and (3) creating a new curriculum. A business example is (1) using an existing transaction processing system (TPS), (2) creating a TPS following general design rules, and (3) creating a new type of TPS.

The purpose of the informing environment is to provide information to the client in a form, level of detail, and sequence to optimize the client's ability to benefit from that information. This component draws heavily upon applied behavioral sciences.

Delivery System. The delivery system refers to the use of information technologies (computing, communications, and so on) that support the implementation of informing environments. This corresponds to the transmission or media component of the communications model.

Information technologies are not limited to computing. Data communication includes video and voice, and even personal contact when it is augmented through planned communication.

Task-Completion System. The driving force behind the creation of informing environments and delivery systems is that a task needs to be accomplished. The task defines what information is needed. This task completion component typically involves a person who has a job at hand. It corresponds to the decoder - receiver components in the communications model.

The task completion system is the sole component that defines the difference among various academic disciplines that comprise Informing Science. In business, the decision-maker commonly is a person (worker or manager) needing help completing a business process. In library science, the task commonly is helping a patron or creating a system to help future patrons. While the task may be different for students, readers or viewers of journalism, or business decision-makers, all share the need to be informed so as to be able to complete their task at hand.

Informing Sciences as a new Discipline

Turchin (1977) developed the evolutionary construct of Meta-system Transition (MST). An MST occurs when a new control level emerges that integrates a set of subsystems at the level below. Developments in IS and other fields that now teach its courses can be viewed in terms of MST as undergoing an evolutionary progress. From this process, a new discipline is emerging, one that subsumes IS and other fields that endeavor to inform their clientele. This emerging discipline is what this paper calls "Informing Science."

Using the term "informing" in this way is not new. Boland (1987) wrote, "…information is the **in**ward-**forming** of a person that results from an engagement with data." What may be new is the acknowledgement that IS is one of many fields in an emerging discipline that share a common goal.

Beyond Informing Science

The elegance of this simple definition is apparent. Less apparent is that other keywords in the definition can be replaced to uncover other linkages. For example, replacing the word "information" with "services" shows the relationship among, say, hospitals, consultants, and exterminators. The hierarchical structure is not well suited to benefiting from or adapting to the multidimensional nature of knowledge.

Implication: University organization no longer suitable

This paper suggests that the many problems of fragmentation first made apparent by IS are due to the very structure of the university and its method of segmenting knowledge creation and dissemination. The problem is most endemic to new fields, which do not fit cleanly in the outdated paradigm on which universities are administered.

Universities use a hierarchical approach to knowledge creation and dissemination. Universities divide knowledge hierarchically into colleges (or faculties) and then departments. The theory behind this categorization of knowledge made sense when the university began. This structuring of knowledge no longer meets the needs of a more complex environment. Indeed, borrowing a phrase from Alstyne (1996), universities tend to Balkanize knowledge into competing clusters of research on the same campus. There are alternate structures, including the matrix structure and the virtual organization.

Under the matrix structure, researchers and teachers who are assigned to a specific administrative unit are assembled into teams based on the needs of the team. A teaching or research project may require, for example, a computing expert and a linguistics expert to collaborate. For research, this approach is used informally at times when colleagues from different fields collaborate on research. However, cross-field collaboration is less than common, and cross-college collaboration is rare. For teaching, any collaboration is rare. The reward structure is particularly ill-equipped to deal with cross-disciplinary work.

The third approach, the virtual organization, has the fluidity of the matrix approach without requiring separate administrative structures. The current university as a virtual organizational would easily accommodate the cross-disciplinary realities of today's world. One method to accomplish this is for faculty to join ad hoc independent teaching or research centers that take on complimentary missions. The centers can establish their own reward structures.

The problem in defining one field has let to uncovering the obvious: knowledge is not hierarchical in nature.

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Chapter 3

Informing Science at a Crossroads: The Role of the Client

T. Grandon Gill and Anol Bhattacherjee

Introduction

Informing science has made remarkable strides as a transdiscipline over the past decade. Its flagship journal, *Informing Science: the International Journal of an Emerging Transdiscipline*, has gained international recognition and has been steadily moving up the management information systems (MIS) journal rankings. The *Informing Science Institute* (ISI), its umbrella organization, has launched numerous innovative and successful journals, is becoming an active publisher of scholarly monographs and sponsors the highly successful *I^{n}SITE* international conference at a period in time when many conferences, especially in the MIS area, see their attendance dwindling.

In the midst of celebrating these accomplishments, we would do well to sound a cautionary note. Other disciplines have raised expectations and subsequently failed to deliver on their promises. Indeed, the core of the rationale for establishing informing science as a transdiscipline was serious shortcomings in the MIS discipline, as seen in Chapter 2. The very real danger is that informing science may well fall victim to a similar set of shortcomings, then vanish into obscurity.

Many reasons have been postulated as to why disciplines succeed and fail. In the case of MIS, these reasons include lack of focus (Cohen, 1999; Benbasat and Zmud, 2003), the need for a broader macro focus (Agarwal and Lucas, 2003), lack of relevance (Benbasat and Zmud, 1999), lack of rigor in some of its qualitative research practices (Dubé and Paré, 2003), the need for more meaningful theory (Gregor, 2006), and too much emphasis on cumulative research tradition as opposed to more professionally focused research (Davenport and Markus, 2003). The very diversity of these diagnoses implies that—while there is a strong suspicion that a crisis exists in the MIS field (Agarwal and Lucas, 2005)—the underlying cause of the crisis remains speculative.

We believe that a better way to explain the success and failure of an academic discipline is to view it as an informing system. In this chapter, we begin by presenting an overview of the informing systems framework, as introduced in Chapter 2 (Cohen's 1999 seminal paper). We then present, as a case study example, an analysis of the MIS discipline using the framework. The results of this analysis highlight the critical, and often overlooked, role played by external clients in disciplinary informing systems. Finally, discuss the implications of these findings for informing sciences, and the types of steps that must be taken if the transdiscipline is to continue making meaningful contributions to the world's knowledge.

Informing Science Framework: An Overview

The informing science discipline emerged as a result of the observation that many disciplines, including MIS, education, library science, computer science and others, were studying the movement of information between senders and receivers in ways that were far more similar than they were different. In the seminal article that launched the discipline, Cohen (1999) defined the transdiscipline as follows:

> The fields that comprise the discipline of Informing Science *provide* their *clientele* with *information* in a *form, format,* and *schedule* that maximizes its effectiveness.

Cohen further defines three underlying precepts of informing science:

1. A framework for characterizing such systems that involves a sender, a communications pathway and a receiver. These are described as the *informing environment*, the *delivery system* and the *task completion environment.*
2. The ability to characterize such systems at many levels. Three such levels include the level at which actual informing occurs, the level at which new informing instances are created, and the level at which overall designs for such systems are specified.
3. The inherent inter-relatedness of the components of such systems: task, technology, structure and people.

Each of these precepts is now explored briefly.

Informing Framework

Chapter 2 uses Shannon's (Shannon and Weaver, 1949) communications model (sender, encoder, medium, decoder and receiver) as the principal lens through which informing systems are viewed. A simplified version of that model is presented in Figure 1.

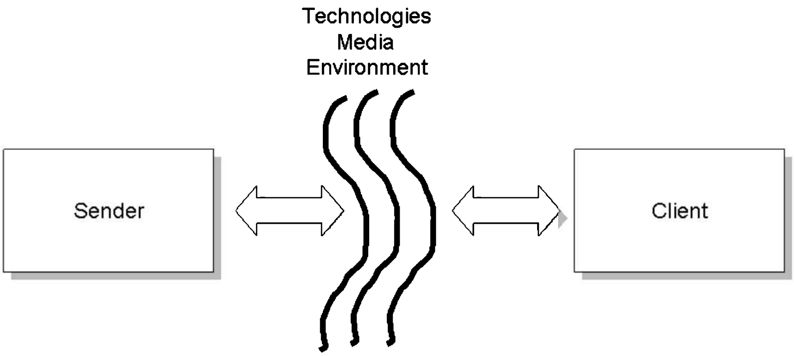

Figure 1: Basic Informing System Model

In practical situations, such a simple model rarely suffices. Many factors make "real world" informing systems much more complex. Examples of these include:

1. Sender and client components are rarely homogeneous. Rather, senders consist of complex *informing environments* that involve subsystems that may, themselves, be informing systems. The same can be said of clients, described in Chapter 2 as *task completion systems*.
2. Senders may be members of multiple informing systems that inform different clients. Drucker (1989), for example, refers to the inherent tension that knowledge workers experience as they divide their loyalties between profession (e.g., accounting, law, medicine) and the organization that employs them.
3. Multiple senders may compete to inform the same client. For example different departments (disciplines) may compete for the same set of students; doctors from different specialties may compete to diagnose the same patients, etc.
4. Multiple communications pathways may be utilized within the same informing system. For example, an advertising campaign

may involve the use of print, broadcast and web-based media in order to reach its entire client base.

5. Multiple clients may be informed by the same sender, and may have to compete for that sender's attention. For example, a patient may find his or her case is neglected as a consequence of the attention a doctor pays to the needs of other patients.

6. Clients may themselves serve as part of an extended informing system. For example, a company may depend heavily on "word of mouth" advertising to gain new clients.

The types of complexities these factors can add to a system are illustrated in Figure 2.

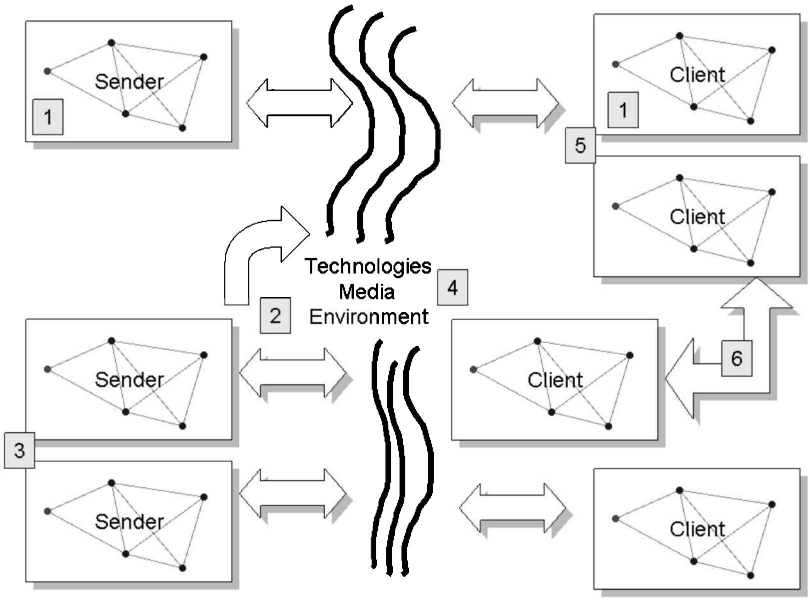

Figure 2: Complexities in "real world" informing systems

Levels of Abstraction

A second precept of informing science is that systems can be examined at multiple levels of abstraction. Chapter 2 lists three specifically: the informing instance itself, the system responsible for constructing new informing instances and, finally, the system that designs new types of informing systems. He presents two examples. The academic example:

teaching a course designed by others (instance), creating a new course (constructing), and designing anew curriculum (design). The business example: using an existing transaction processing system (TPS; instance), building a new TPS from existing rules (constructing) and creating a new type of TPS (design). From these examples, we see that these different levels of abstraction may also correspond to different levels or areas of the informing system where the organization is housed. We may also conclude that the boundaries of informing system levels are somewhat permeable. For example, redesigning an existing course and designing a new course obviously represent part of a continuum between instance and design.

Interrelatedness

A final precept of informing science is that the elements of an informing system (e.g., task, technology, structure and people) interact in a manner that is sufficiently complex such that changing the characteristics of one component (e.g., technology) can have a significant impact on the behavior of other components, as shown in Chapter 2. Systems with such characteristics tend to resist decomposition (Simon, 1981), meaning that behavior is best examined at the system level, since understanding individual component behaviors does not necessarily lead to a valid picture of how the system as a whole will behave—indeed, such is essentially how Simon defines system complexity.

An important implication of this interrelatedness is that technology must play a particularly central role in informing science research, since it tends to be the element within such systems that is changing most rapidly, and is therefore the engine that drives much of the change in system behavior. A further implication of interrelatedness and technology's role is that informing science research must, of necessity, proceed at a rapid pace, since technology-induced changes to system behavior will tend to occur continuously. If the time between observation and dissemination of such research be too great, the behaviors being observed will likely cease to be relevant.

An Informing Science Case Study: The MIS Discipline

The MIS field has always played a pivotal role in informing science. Much of the motivation for establishing the informing science transdiscipline came from observed weaknesses in MIS (Cohen, 1999). Equally important, many of the participants in informing science are also participants in the MIS discipline, one of the disciplines where the journal *Informing Science: The International Journal of an Emerging Transdiscipline (InformSciJ)* has been ranked (e.g., Pfeffers and Tang, 2003). Finally, there is considerable overlap between the management-technology focus of MIS and the informing science framework. Indeed, the latter can be viewed as a powerful lens through which to view the former.

The Current Situation in MIS

As previously noted in the introduction, there is a strong contingent within the MIS research community who believe that the discipline is in crisis (Agarwal and Lucas, 2006). Such concerns are not new. Cohen (1999) observed found that field was not well differentiated from applied computer science, fragmented in its research (citing Swanson and Ramiller, 1993) and teaching (citing Davis, et al., 1997), and taught material that was also being presented in other disciplines (citing Cohen, 1997). Additional critiques have decried the field's pursuit of rigor over relevance (e.g., Benbasat and Zmud, 1999; Davenport and Markus, 1999), but have differed widely in their prescriptions—ranging from the need to develop more "cumulative theory-based, context rich" research (e.g., Benbasat and Zmud, 1999) to moving the discipline's emphasis towards practice-focused disciplines, such as law (e.g., Davenport and Markus, 1999). Moreover, concerns regarding the need for greater rigor in MIS case studies (which tend to be, presumably, high on the relevance scale) have also been raised (e.g., Dubé and Paré, 2003).

Although the existence of an "MIS research crisis" is still far from universally accepted, what is recognized by virtually everyone is the fact that enrollments in MIS programs have dropped substantially. Some institutions with large undergraduate programs (e.g., Georgia State University, University of South Florida, Florida Atlantic University)—each having MIS major enrollments in excess of 700 students at their peak—have reported declines in the 70-80% range since 2001. Moreover, these declines have persisted despite that fact that the decline in the IT workforce that began during the heyday for MIS enrollments actually began rebounding in 2003, based on U.S. Bureau of Labor Statistics data (http://www.bls.gov/OES/) and, by 2005, had exceeded its year 2000 peak. The impact of this is now becoming of grave concern for future MIS doctoral students. As it stands, absent unusually high demand for faculty—such as that caused by the rapid build up of enrollments that occurred in the later 1990s—only about 5% of all MIS doctoral students are predicted to be able to achieve the research standards of research extensive and elite universities (Dennis *et al.*, 2006). Barring another jump in enrollments (that would serve to motivate a relaxation of these standards), the prospects of the untenured IS faculty member would seem to be grim indeed.

It can, of course, be argued that these depressing prognostications ignore the history of the MIS academic discipline. After all, a similar (although much less severe) drought in MIS academic hiring occurred in the early 1990s. And, scarcely half a decade ago, the great fear was that a permanent shortage of MIS faculty would exist (Freeman *et al.*, 2000). The fundamental question therefore becomes: Is MIS experiencing just another in a long series of fluctuations, or is this the beginning of the death spiral of the discipline? To answer this question, simply projecting current trends is likely to prove woefully inadequate—as, indeed, it has in the past. We believe that a much more effective approach involves looking at the MIS discipline as an informing system.

The Academic Informing Systems

Unlike some research disciplines—such as engineering and medicine, where research advances can occur in many settings (e.g., in industry, hospitals, government-sponsored laboratories)—the MIS discipline is housed nearly entirely in academic institutions, mainly universities. For this reason, the disciplinary informing system needs to be studied as it relates to the institutional informing system, which supplies most of its resources (e.g., salaries, research support, facilities). Furthermore, as was noted in the earlier introduction to informing systems, these systems exist at three levels—two of which involve participants that share two roles. For the disciplinary informing system, the instance role is played by the faculty member, who conducts research and writes papers according to the guidelines of the discipline (at least if he or she wishes to be published). At the construction level, there is the department—responsible for creating new informing instances (i.e., doctoral students who become faculty) and for setting hiring priorities that help determine the research direction of the department. At the creation level, there are the journals and eminent scholars of the field, whose recommendations essentially define where the field will go, through editoral policy, willingness to co-author, external reviews of promotion and tenure candidates and through setting the agenda for disciplinary conferences. For the institutional informing system, supplying resources to the disciplinary informing system helps to satisfy its research mission. More important, however, faculty members—in their teaching capacity—are also fundamental elements of the instance level of the informing system for which students are the client, and departments, in their administrative capacity, serve both to organize faculty (through teaching assignments) and to create new course and program instances. Only at the creation level do the participants in the institutional informing system (e.g., university leadership, trustees) and the disciplinary informing system (e.g., journal editors, eminent scholars) diverge substantially.

Another source of complexity in academic informing systems is that multiple clients exist for both disciplinary and institutional systems. For disciplinary informing systems, whose principal activity is research, these clients are served by three types of research:

- *Pure research:* Research that is principally aimed at internal clients, that is to say, clients within the discipline itself. Such research is an essential part of a discipline's ability to advance since—at least in theory—it represents a form of organizational learning through changing the theory-in-use over time (Gill, 1994).

- *Applied research:* Research that is directed towards other clients. Among these are included practitioners, interested members of the public or other disciplines (e.g., applied mathematics describes the use of mathematical techniques in physics, chemistry, economics, etc.)

- *Scholarship of teaching (SOT) and ancillary research:* Research that is specifically directed towards improving the effectiveness of teaching (i.e., informing student clients) or other aspects of the discipline. It makes sense to distinguish SOT/ancillary research from other forms of applied research because it can easily draw upon an entirely different set of reference disciplines (e.g., psychology, education) than those of the discipline itself (e.g., engineering, science, fine arts, etc.)

These research categories (along with a fourth, unrelated research) are illustrated in Figure 3, which presents two dimensions: external-internal clients, and disciplinary-other paradigms used to conduct the research.

	Discipline Paradigms	**Other Paradigms**
Internal Client	**Pure Research**	**Scholarship of Teaching and Ancillary Research**
External Client	**Applied Research**	**Unrelated Research**

Figure 3: Categories of research

Institutional clients, on the other hand, involve many different constituencies (Trieschmann et al., 2000), which could include students, regulators, employers, benefactors, community leaders, accreditation organizations, ranking organizations, and others. Only a small number of these may overlap a discipline's clients (e.g., students, practitioners/employers, granting agencies, etc.) These relationships are illustrated in Figure 4.

As suggested by the dotted line down the middle of the diagram, participants in both informing environments (e.g., colleges, departments, faculty members) face choices regarding how to allocate their activities between systems. All other things being equal, it is reasonable to suppose that such allocation will, to a great extent, be determined by how it impacts the participant's access to resources. For the individual faculty member with an active research program, this pull is likely to be in the direction of maximizing disciplinary participation. For department/college participants, on the other hand, the greatest return is likely to come from activities that impact position in the institution's resource queue. They are therefore likely to gravitate towards increased institutional participation.

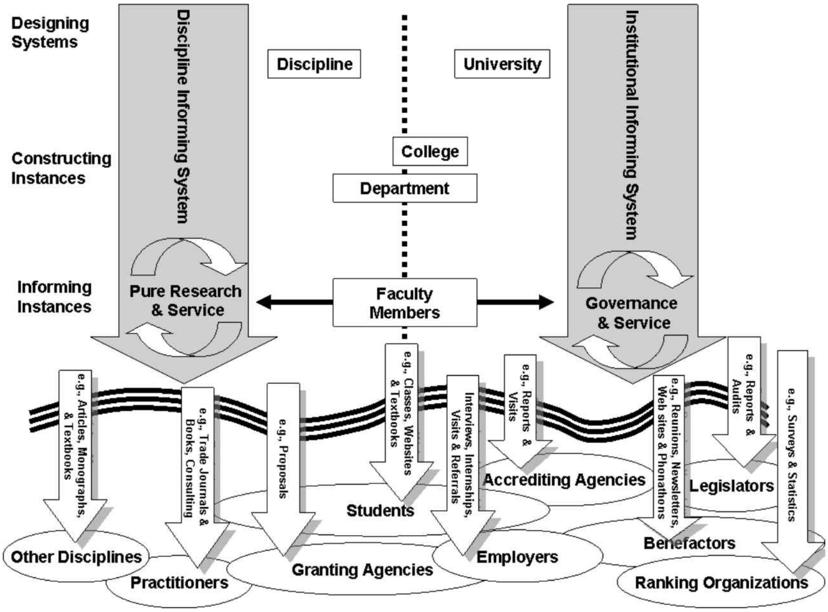

Figure 4: Disciplinary and Institutional Informing Systems

The paired informing system perspective also suggests that the degree of overlap between a discipline's clients and the clients of a specific institution is likely to have a profound effect on how well that particular discipline thrives within the institution. The reasoning here is as follows. Although disciplinary informing systems tend to be largely self-regulating, most (with engineering and medicine being notable exceptions) tend to be nearly entirely dependent upon the institutional informing system for resources. Thus, it will ultimately be the institution that determines the percentage of available resources that are allocated to each discipline's activities. Assuming any type of rational budgeting approach is utilized, a key component of the decision will be the degree to which each marginal dollar allocated to a discipline yields marginal gains amongst the institution's various client constituencies. It should be noted that such a calculation would not normally involve the intra-disciplinary research contributions of the faculty—except to the degree to which they impact the institution's clients (e.g., the department's pure research activities might be bringing in substantial grants with associated institutional overhead components; a strong research reputation in a particular department might lead to a higher overall ranking of the university in U.S. News and World Report; reducing funding to a particular department might impact an institution's accreditation status).

The MIS Informing System

When viewing MIS as an informing system, our first question becomes: Who are the external clients? As a discipline allied with business research, there are two clients we would invariably expect to find: practitioners and students. In addition, we might plausibly anticipate that the widespread impact of IT across business functions would motivate researcher clients from other disciplines to examine our research. Thus we ask: how well is the discipline informing these three potential clients?

Practitioner Clients

There has been considerable debate regarding the degree to which MIS research is actually informing practitioner clients. The two sides of the debate, however, do not appear to cover the full spectrum of possible opinions. Instead, opinions range from "the business community would question the relevance of IS research as published in the leading journals of our field" (Benbasat and Zmud, 1999) to "the extent to which IS research is relevant to IS practice is, objectively speaking, unknown" (Lee, 1999). Moreover, there is also disagreement as to the pathway through which the discipline should inform its practitioner clients—going directly to senior practitioners or informing through students (Davenport and Markus, 1999), with textbooks playing an important role (Lyytinen, 1999). What can be observed empirically, however, is that practitioner participation in MIS research—at least in the form of collaborative authorships and contributions to the discipline's premier journal (*MIS Quarterly*)—has fallen precipitously over the past quarter century, from 41% (in 1980) to 0% (in 2005), as shown in Table 1.

Anecdotal observations seem to confirm the patterns observed in the table. For instance, the Society for Information Management (principally a practitioner group) chose to stop supplying its members with free subscriptions to *MIS Quarterly* in 1995, at which point most members dropped their subscription (Benbasat and Zmud, 1999).

Further evidence of the lack of priority placed on the practitioner client is the fact that practitioner-focused journals tend to be rated well below academic journals in IS journal rankings. For example, on the comprehensive AIS ranking list (see http://www.isworld.org/csaunders/rankings.htm), Harvard Business Review tops the list at 8th place, followed by Sloan Management Review at 19th place and California Management Review at 43rd place. The significance of these placements is underscored by the fact that "elite" journal status in MIS is normally reserved for the top two finishers and that a third contender, *Communications of the ACM*, dropped out of contention after "having shifted its focus to applied, practitioner-focused articles" (Dennis et al., 2006). There are also examples of situations where MIS-related issues are addressed in the practitioner community without any considering any of the findings of the academic research discipline. For example, a recent report prepared by the U.K. National Audit Office (NAO, 2006) focused on delivering "successful IT-enabled business change"—an area clearly central to MIS research—without making a single reference to MIS disciplinary research findings.

Table 1: Industry and academic author contributions to MISQ at 5 year intervals

Year	Count of Articles	Academic Authors	Industry Authors	Total Authors	Percent of Authors from Industry
1980	18	16	11	27	41%
1985	23	32	8	40	20%
1990	23	45	11	56	20%
1995	24	60	3	63	5%
2000	23	55	3	58	5%
2005	28	66	0	66	0%

Taken together, these observations strongly suggest that the MIS disciplinary informing system supports very limited pathways, at best, from its sender side (researchers) to its practitioner clients. Although the weak academic-practitioner linkage has long been recognized by the discipline—with its frequent calls for increased relevance—it is not clear what purpose relevance would serve given that the informing system does not currently place a premium on the communications linkages that would ensure strong researcher-to-practitioner information flow. If it did, the field would tend to place a higher value on publishing in practitioner journals, on writing the types of books that one sees in airport gift shops, and upon engaging in consulting activities (many of which are applauded, or at least tolerated, by other business disciplines such as management). It could be argued, of course, that the reason for such a trend is that the MIS discipline has matured and became more theoretical, scientific, more methodologically (and even mathematically) sophisticated and demanding—all of these making it less accessible to managers. But this is just another way of saying that the discipline has chosen to focus on informing itself, rather than on placing a priority on informing activities that meet the needs of the practitioner client.

Student Clients

The second natural client for the MIS discipline is its students. In its early years, the discipline was blessed with ever-increasing enrollments that it could have easily attributed to its own efforts. These increases reached a crescendo around the time of the millennium, when massive faculty shortages—created by annual double-digit increases in MIS program enrollments—were being experienced throughout the U.S. With the bursting of the Internet-bubble and the information technology (IT) industry slowdown that accompanied the successful avoidance of a Y2K disaster, the situation changed radically. Although we know of no authoritative source that yet identifies the full magnitude of the downturn (educational statistics lag by several years), anecdotal surveys of faculty conducted at conferences and in other settings suggest that few programs experienced downturns of less than 50% from their peak (George, *et al.* 2004) and that many—especially at larger institutions where students had many alternative majors to choose from—experienced declines as high as 80%. Since it is doubtful the field is entirely to blame for the crash in enrollments, it is equally reasonable to question whatever credit it took for the prior rise.

It turns out to be very difficult to make a rigorous assessment of the degree to which student clients are being served, since both faculty and students are, potentially, participants in both the disciplinary and institutional informing systems presented in Figure 4. Since research doctoral students can appropriately be characterized as examples of the instance construction process, doctoral courses and research seminars would fall under the heading of internal informing. Professional doctorates clearly represent a different case but, at the present time, do not play a major role in U.S. programs (Gill and Bhattacherjee, 2009). Similarly, it would be unreasonable to expect ongoing faculty research activities to make a major contribution to introductory survey courses. Thus, such activities can be characterized as purely institutional in nature; faculty members acting in their capacity as participants in the institutional informing system. This characterization is consistent with the label "service courses" often applied to such teaching.

After eliminating doctoral and service courses from the mix, what remains are MIS-specific courses that are taught at the undergraduate and graduate level to students whose principal goal is **not** to become MIS researchers. Because of the highly dynamic character of IT in general, we would expect cutting edge findings from MIS research should rapidly make its way into the classroom. That expectation comes with a large proviso, however. Specifically, it assumes that what we research overlaps what we teach.

An assessment of overlap between teaching and research interests, compiled from the AIS database, is presented in Figure 5. It takes four core course topics that are widely taught at both the undergraduate and graduate levels and compares them with faculty research interests. The figure presents a paradoxical picture. On the one hand, those faculty members who research a given area are very likely to teach it. For example, 74% of AIS members who research telecommunications also teach that subject. On the other hand, most of the AIS members who teach a particular subject are not doing research in that subject. For example, 85% of the individuals teaching programming are not doing research directly or indirectly related to programming.

The explanation for proposed for this situation derives from the nature of the research conducted by the disciplinary informing system. Specifically, MIS has always engaged in research in two areas: the behavioral and the technical. Over time, however, that research has increasingly favored the behavior. MIS educational programs, however, have retained a large technical component. Thus, a mismatch has developed between what MIS teaches and what it researches. If a researcher happens to engage in technically-focused research, opportunities to teach the same content tend to be readily available. On the hand, if the researcher studies behavioral topics, he or she is likely to have to teach some technical courses since there just are not sufficient technical researchers available to support the demand.

None of these comments can be interpreted as impugning the quality of technical content being taught by behavioral researchers. What it does suggest, however, is that the research discipline has allowed itself to become misaligned with the needs of its external student clients.

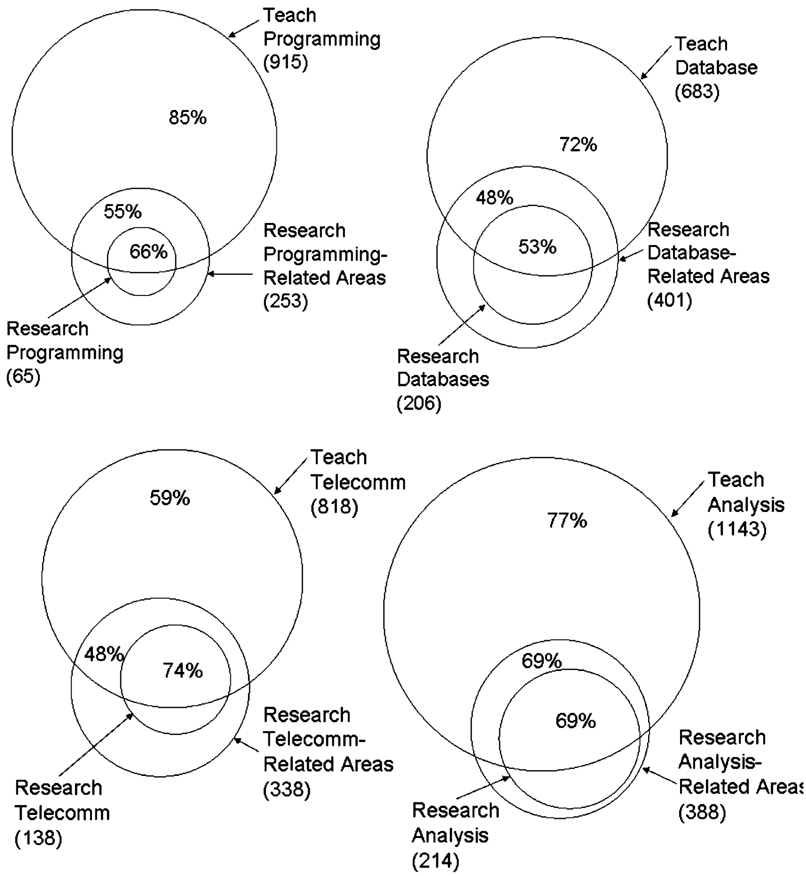

Figure 5: A comparison of teaching and research interests for AIS members. Numbers in the non-overlapping portion of the large circle represent percentage of faculty members who teach in a particular area but do not research in that area. Numbers in the smaller overlapping circles represent the percentage of faculty who perform research in the specified area (or related area) and also teach in it. (Adapted from Gill and Bhattacherjee, 2009)

A similar argument might be made with respect to the low level of status accorded to scholarship of teaching research (SOT) within the MIS discipline. For example, the top ranked MIS journal focused on teaching, the *Journal of IS Education*, ranks 80th on the AIS composite list. While education-related research is denigrated in many fields (outside of education), a healthy respect for SOT within a discipline suggests a high priority being placed on informing student clients. Interestingly, education-oriented research has much higher status in computer science—where education-related conferences are highly competitive and substantial funding is available for teaching-related research from agencies such as the National Science Foundation (NSF).

Researcher Clients from Other Disciplines

One remaining set of possible clients that warrants consideration is other disciplines. Indeed, there has been an argument made that MIS *should* serve as a reference discipline for other fields (Baskerville and Meyers, 2002). At the same time, those authors state:

> Since IS was defined early on as an applied discipline, the conventional wisdom has held that our research is targeted primarily at IS researchers and practitioners—indeed, many IS journals explicitly require authors to discuss the implications of their work for these two audiences. That our research might be of interest to researchers or practitioners in other fields seems not to have been considered. (p. 1)

Citation analysis seems to support the view that MIS research is presently doing little to inform other business disciplines. In a study of out-of-field citations among top journals (Wade et al., 2006), MIS scored near the bottom (just ahead of ethics) with 0.19 out-of-field citations per article (for comparison purposes, General Management averaged 5.03, Organizational Behavior scored 1.96 and Finance scored 1.30; p. 254). Furthermore, the same research found that non-MIS citations to MIS articles have been dropping over time (since their peak in 1997), with external citations as a percentage of citable articles dropping even faster, since 1992 (p. 259). The situation appears even worse when MIS is contrasted with International Business—another relatively young discipline—where outside citations have risen materially during the same period (p. 260).

Having provided evidence that practitioners, students and other disciplines serve a very limited role as clients in the MIS informing system, the question remains: Whom is MIS informing? The obvious answer is other members of the MIS discipline. In other words, nearly all informing activity is directed towards pure research (i.e., enhancing the informing environment). There are a number of reasons for believing this to be the case:

1. All available MIS departmental rankings appear to be based strictly on publications in a small number of MIS research journals

2. MIS departments are relying heavily on metrics such as journal impact factor in assessing individual research contribution. It would be hard to devise a metric better constructed to reward pure research activities. Moreover, the disciplines premier journal—MIS Quarterly—has recently achieved the highest impact factor of all business-related journals. This means that members of the discipline are both reading and citing each other.

3. The field is continually trying to determine what is and what is not MIS (e.g., Benbasat and Zmud, 2003; Hevner et al., 2004; Agarwal and Lucas, 2005). In a discipline with clearly identified clients, the needs of the task completion system would determine what was, and was not, an appropriate set of problems to address.

4. Despite frequent calls for a re-evaluation of priorities (e.g., Benbasat and Zmud, 1999; Davenport and Markus, 1999), the discipline's research continually gravitates towards emphasizing rigor (a measure of logical quality control in the sender's informing environment) over relevance (the degree to which research findings are likely to impact the client's task completion environment).

5. As suggested by the earlier Figure 4, faculty members tend to have some discretion with respect to their level of participation in the institutional and disciplinary informing system. Incentives for individual faculty, however, are strongly biased towards active participation in the disciplinary informing system. Specifically, the two most effective ways of increasing an MIS faculty member's compensation are to publish in

refereed journals and to change institutions (Gill, 2001). Both of these tend increase the individual's motivation to participate in pure research aimed at top-ranked MIS journals. The latter tends to undermine loyalty to the institution, as well.

Thus, evidence clearly points to a conclusion that the principal role of the MIS disciplinary informing system is, at the present time, to inform itself.

An Unpleasant Scenario for the Future of MIS Research

So what are the implications of a discipline that, after more than 30 years, still mainly focuses on informing itself? Ironically, the short run implications for active participants in the discipline may seem mainly positive. Specifically, dramatically reduced enrollments lead to smaller classes, on average, and make it easier to make a case for reducing teaching load in favor of increased research assignments. Since, during its bubble years, MIS was frequently criticized for its excessive reliance on adjuncts and instructors, those temporary faculty—who were never active participants in the disciplinary informing system—are the ones most likely to experience layoffs. Furthermore, external requirements on the institution (e.g., new accreditation requirements that MIS be incorporated into the business curriculum) ensure that some new MIS teaching opportunities will be created, perhaps even enough to find placements for faculty displaced by the overall shrinkage in student demand. The group that has the most to lose during this period is the doctoral students. A relatively small number of these will be able to find positions at research schools; far fewer still will be able to meet the requirements for tenure (Dennis et al., 2006). To borrow a phrase used to describe junior faculty at Harvard, they will be like victims of a terminal disease—treated with great compassion but with the unspoken understanding that they won't be around for very long.

Barring a major rebounding in student enrollment—an external effect that would invalidate this entire scenario—the medium term is likely to bring substantially more pain to the typical participant in the research discipline. Given that student demand doesn't drive institutional motivation to supply resources to MIS departments, institutions would seem to have two choices. The first would be to starve the departments. There would be very little danger that faculty would leave during extended periods of contraction. Furthermore, even if they were to leave, there are few MIS courses that could not be outsourced to other disciplines (e.g., accounting information systems, engineering, computer science, management).

As a second strategy, some institutions could use MIS as a means of increasing their overall ranking as research schools. The reasoning here is as follows. At the very top schools, if MIS is not serving any useful external clients, they can simply starve the department for resources and their faculty will tend to move elsewhere. That creates an opportunity for less highly ranked schools to acquire a stellar faculty—probably more easily than would be the case for any other discipline. Doing so could meet the institution's needs for informing its "ranking" clients which, in turn, inform other constituencies (e.g., students, benefactors). In effect, MIS becomes the low hanging fruit. Some tantalizing evidence that such a process may already be taking place can be found in the 2001 ranking of business research areas (Dennis, *et al.* 2002). The top 10 of these are shown in Table 3.

What is surprising about these ratings is the degree to which extremely highly rated private schools, with large endowments, have MIS departments with very low ratings (e.g., 37th at Wharton, 18th at Harvard, 45th at Stanford, not even present at Chicago). Further supporting the trend is the fact that every school with a top ten MIS program in the top 10 schools also experienced a rise in overall ratings. For two of the schools (UNC Chapel Hill and Indiana, the jump was substantial). A reasonable speculation would therefore be that acquiring a strong MIS research faculty could be part of a concerted effort to move up the rankings. Also interesting is the fact that the only other discipline where a similar pattern occurs is in POM (production and operations management), which experienced at similar drop in interest a few decades ago (largely as a result of U.S. manufacturing's move off shore), and has already been absorbed by other departments at many institutions.

The problem with institutions using MIS as a means of elevating their rankings is that the approach will only work at a limited number of sites. An institution would need an MIS area far higher than its overall research average to produce a worthwhile ratings impact. In addition, as more and more highly ranked institutions come to view MIS as a disciplinary pariah, the weight it is given in research rankings, along with the accompanying impact, is likely to decline. In this context, it is worth observing that among Business Week's top 20 schools, not a single school now requires an MIS course as part of its MBA program

(Gill and Bhattacherjee, 2009). Thus, in the long term, there is the danger that the very existence of an MIS department will be taken as evidence that the school is a "lesser" institution.

Table 3: Rankings by discipline from Dennis et al. (2002)

Rank 1997-2001	Rank 1986-1998	University	Accounting	Finance	Ins, IB	Management	MIS	Mgt. Science	Marketing	POM
1	1	Pennsylvania	1	2	1	4	37	2	1	63
2	2	Michigan	7	14	10	1	14	7	13	8
3	9	Harvard	9	3	12	11	18	11	8	49
4	3	Stanford	4	9	69	7	45	5	15	
5	5	Chicago	3	1	35	37		24	14	
6	23	UNC - Chapel Hill	2	11	28	17	9	32	31	9
7	8	Texas - Austin	12	12	7	5	7	9	4	95
8	10	Northwestern	5	10		6		8	12	
9	6	Columbia	10	8	41	14		1	3	
10	21	Indiana	8	46	36	16	2	55	18	90

If MIS does not change direction and make a concerted effort to find external clients in the near future, the long term prognosis for the MIS discipline would seem to be very grim. MIS departments are likely to shrink and then, finally, be absorbed by other departments at nearly all institutions—much the way management science and production/operations management have already been. Although MIS research will doubtless continue to exist, it will do so at the forbearance of other disciplines. Without departments—the instance construction engine of the informing system—there will be far fewer doctoral students. That will, in turn, lead to a shrinking of research output and a graying of the professoriate. What participants remain in the system a few decades hence will doubtless look back to the late 1990s as "the good old days" unless radical changes happen soon.

Clients for Informing Science

The purpose of presenting the MIS case study was twofold. First, it illustrates the power of informing science lens in analyzing complex systems. Second, it should be viewed as a cautionary tale. As illustrated by the earlier Table 1, MIS started as a partnership between academia and industry clients, and was later fueled by skyrocketing demand from student clients. We have proposed that it is only through ignoring these clients that it reached its current perilous condition.

Informing science was started with neither a practitioner base nor a student base to work with. It is, therefore, high time for the discipline to "eat its own dog food" (a phrase used by both Microsoft and Sun to describe using the same technologies that they sell to their customers for the purposes of running their internal systems) and apply informing science framework to analyzing its own situation. Specifically, it is time to identify the specific types of external clients that are to be informed in the future.

Criteria for Identifying Plausible Clients

As implied by the previous discussion of the MIS disciplinary informing system, identifying and committing to serve specific clients greatly reduces a discipline's need for introspective (and interminable) discussions regarding what does and what does not constitute valid disciplinary research. The informing science framework, however, suggests that not all clients are created equal. Specifically, we propose that at least four criteria must be met for a client to be considered ideal:

- *The client has an unaddressed set of problems:* Just as the MIS field emerged as a separate discipline largely as a consequence of the software crisis of the late 1960s and early 1970s, clients with serious issues not currently being effectively addressed by other disciplines will tend to exhibit the greatest receptivity to new perspectives.
- *Serving the client provides access to resources:* Unless the members of a discipline have unlimited financial resources, a condition that is highly unlikely, the ideal client can provide access to needed

resources in two ways. First, it could supply resources to the discipline directly in return for informing activities (e.g., through consulting fees or grants). Second, it can be a significant client of the institutional informing system, in which case fulfilling the client's need provides a justification for acquiring a share of institutional resources.

- *The members of the discipline have the expertise to address the client's unaddressed problems:* Just because a potential client has significant unaddressed problems does not necessarily mean that any sender can be effective in addressing them. An interesting example of this is the recent call for the MIS to place greater focus on design research (Hevner et al., 2004). The researchers make a compelling case for the need for such research and also identify suitable clients for the research. The greatest challenge presented by the proposal can be illustrated using the researchers' own words: "The primary goal of this chapter is to inform the community of IS researchers and practitioners of how to conduct, evaluate, and present design science research" (p. 77). What is the likelihood that the members of a discipline that has become dominated by a behavior approach to research (as asserted by the researchers themselves) will have the skills required to embark on a totally different research agenda? And, if they do not have those skills at present, how long will it take to acquire them?
- *One or more resonant communications channels exist, or can be created:* Some means of moving information from the discipline to the client must be present if the system is to inform. The use of the term *resonance* is intended to imply amplification of the message as it moves through the channel (e.g., as an instrument amplifies the sound produced by a vibrating string) and further amplification as it reaches the client (e.g., as a well-designed concert hall enhances, rather than deadens, the sound).

The last of these criteria warrants some additional comment. As noted in the MIS example, a discipline often views its research in terms of a tradeoff between rigor (assessed at the sender-side informing environment) and relevance (related to the client-side task completion system). In informing system terms, however, this ignores an important part of the system—the channel. We believe, therefore, that the criteria for judging effective research need to be augmented with a third dimension that defines the ability of that research to bridge the divide between sender and client. In Shannon's (Shannon and Weaver, 1949) terms, this characteristic—which we refer to as *resonance* (both because it conveys the proper image and because it alliterates with the other two terms *really* well)—is particularly focused on how the message is encoded, the transmission medium, and how it is decoded in a form that is appropriate for inducing changes in client activities. An additional aspect of resonance is the degree to which secondary informing activities (sympathetic vibrations in physical terms, "word-of-mouth" in a business context) are invoked within the client's internal systems. Some MIS discussions of rigor versus relevance view resonance as an element of relevance (e.g., by including publication outlet as part of the debate, as in Davenport and Markus; 1999). Others view outlet as less important than the need to better train practitioners to read MIS research in its unabridged form (e.g., Lyytinen, 1999). We believe that both perspectives ignore the power of resonant messages, even in the absence of rigor or relevance. To use a U.S.-specific example, consider the power of college athletics—particularly football and basketball—as a means of communicating with various institutional client constituencies (e.g., potential students, alumni, benefactors, legislators, etc.) Although the precise role that fielding championship football teams plays in fostering research and informing students is obscure, the resonance that such a team can produce within the institution's client base could well justify the massive injection of resources that developing such a program requires. For example, few casual observers would guess that the authors' own institution, University of South Florida, has both a substantially larger student body and substantially more external funding than its northern neighbor, Florida State University. Where the latter has a huge advantage, however, is in its long-standing ability to field football teams that are nationally competitive. Viewed in the context of informing resonance, it makes perfect sense that the football coach—not the president or the most eminent professor—tends to be the most highly paid individual at such institutions.

Examples of Plausible Informing Science Clients

To illustrate how the above criteria might be applied, it is useful to propose some examples of clients—inspired by the analysis of the present chapter—that might fit well into the portfolio of clients that the informing science discipline serves.

Distance Learning Educators and Administrators

The topic area of distance learning has been studied extensively, both in the field of education and in the disciplines that employ it. Despite this fact, opinions on the subject that are nearly polar opposites persist (e.g., Hirshheim, 2005; Gill, 2006) and myths abound (Sarker and Nicholson, 2005). One likely explanation for the lack of consensus is that the establishment of distance learning programs invariably involves the interaction between disciplinary and institutional informing systems. What is particularly intriguing about this area, however, is that polar opposite positions exist within both informing systems. For examples, some administrators may strongly support distance learning adoption for reasons of achieving cost savings, to leverage scarce facilities and/or to meet the needs of working student clients. On the other hand, they may resist it on the basis that it will lead to the perception—amongst employer and rating clients—that the institution is opportunistically ushering in reduced standards. Disciplinary participants, on the other hand, may condemn it for its impact on their rhythm of life, for reducing the richness of their interactions with students, for the extra work it entails, and/or for the difficulty in maintaining quality control in assessments. Other faculty members, however, may see it favorably through the lens of how it increases the range of content and experiences that can provide to students and the increased time/place flexibility it gives them in their personal and research activities.

The study of distance learning from the informing science perspective would be a good fit with the plausible client criteria. Specifically:

- As already noted, there exists a wide range of opinions regarding both the educational effectiveness and institutional desirability of distance learning, and little evidence that a consensus is forming. Furthermore, implementation of such programs requires substantial coordination between disciplinary and institutional informing systems, as well as the deployment of substantial technical infrastructure. The large number of participating systems suggests that a single discipline (e.g., education) is less likely to be able to address the entire problem than a transdisciplinary approach. Indeed, a plausible explanation for the existing lack of consensus on the subject is that, too often, it is being approached from a single disciplinary perspective.

- Inasmuch as the institutional informing system would be a major beneficiary of advances in this area, it is reasonable to suppose that such research would be viewed as worthy of some allocation of institutional resources.

- Within the informing science transdiscipline there already exists the appropriate balance of expertise, with educational (e.g., education, library science), managerial (e.g., MIS) and technological (e.g., computer science, instructional technology) perspectives all being well represented.

- With faculty and institutional administration being the clients, existing channels (e.g., articles in scholarly journals) may be effective in producing resonance—indeed, the academic clientele is one of the few for whom such outlets resonate. Furthermore, the Informing Science Institute already publishes a number of journals directly (e.g., *Interdisciplinary Journal of Knowledge and Learning Objects*) or somewhat (e.g., *Journal of Information Technology Education, Issues in Informing Science and Information Technology Journal*) related to the subject area.

Disciplinary and Institutional Leadership

A similar clientele, albeit at a somewhat higher level, would involve the leadership of the various disciplines and academic institutions. As illustrated by the present chapter, academic institutions face a major challenge is determining how to allocate resources between disciplinary informing systems. Similarly, we can easily locate complaints about incomprehensible administrative priorities that are voiced by faculty members—just look at any faculty union newsletter. Although studying the interaction between these systems would be something of a departure from informing science's roots as an alternative perspective on MIS, the only type of research program that would have any chance of being effective in servicing this clientele would have to be transdisciplinary in nature. To what extent would a college of engineering be agreeable to priorities established by the educational leadership discipline (situated within the college of education) or the sociology discipline (within arts and sciences)?

In some respects, the study of disciplinary-institutional interactions fits a similar plausibility profile to that of distance learning. Specifically:

- The problem of allocating academic resources is increasingly being recognized. Since the early 1980s, the cost of a higher education has been increasing faster than almost any other category of goods or services (including medicine), with college costs increases outpacing family income growth by a factor of three (Boehner, 2003). The long term consequence of this trend is likely to be the need for substantially greater institutional cost containment measures than are currently in place, creating a greater need for prioritizing support to disciplines.
- Once again, with the institutional informing system being a major beneficiary of advances in this area, it should be deemed resource-worthy.

Other areas of fit are somewhat less compelling. On the other hand, it is hard to identify any other discipline or transdiscipline that is currently better positioned for investigations in this area. For example:

- In additional to the business, communication, library science and education disciplines, participants in informing science also include members of many other disciplines, such as liberal arts and engineering. Of particular note, philosophy—likely to be a key element of any investigations—is already represented in contributions to the *InformSciJ,* related journals and this book (e.g., see Chapters 4, 6, 10, 13, 14, & 21).
- Although faculty and institutional clients can, to some degree, be served by traditional journal articles, as the range of disciplinary clientele being served grows, so must the range of channels that are to be used. Scholarly monographs (not collections of loosely related articles bound in book form), that are largely discounted by some disciplines carry the greatest weight in others. Electronic publications are acceptable in some areas and deemed entirely inappropriate for others. Case studies are applauded in some areas, reviled for being non-rigorous by others. Technology-based artifacts may be treated as the ultimate proof of concept by one group and may intimidate or alienate another. While recognizing that informing science has a distance to go in supporting the full range of channels necessary, it is also reasonable to celebrate how far it has come. For example, the *Informing Science Institute*

(ISI) currently supports both electronic and print formats for all its journals and books. ISI is also developing repositories suitable for technological artifacts (e.g., the *Teach IS* site at http://teachis.org/). In 2006, it launched two new journal specifically directed at a clientele of faculty and doctoral students across all disciplines, one being a traditional journal (*Journal of Doctoral Studies*), one publishing case studies (*Informing Faculty*). Thus, while progress must (naturally) continue, there are few organizations currently better positioned to inform the diversity of clients in this research domain.

Before leaving the subject of plausible clients we must emphasize, once again, that the examples being presented are not intended to identify *the* appropriate clients for informing science. Rather, they are presented to illustrate the type of analysis that could be determined in assessing the appropriateness of a possible client and to suggest possible candidates for inclusion in what will undoubtedly be a portfolio of informing science clients.

Complex Systems: A Transdiscipline Success Story

In addition to identifying plausible clients, participants in the informing science discipline might do well to consider the experiences of other transdisciplines that have effectively navigated the pitfalls of establishing a new informing system. One example that immediately springs to mind is the study of complex systems (sometimes also referred to as complex adaptive systems). The underlying premise of this discipline—much like that of informing science—is that certain types of systems (incorporating many interconnected elements that interact with each other) begin to exhibit certain characteristics (e.g., punctuated equilibrium; Bak, 1996) regardless of the context in which they were observed. Where that discipline differs most markedly from informing science is that their focus is on the behavior as the system as a whole, whereas informing science focuses on the behavior of coupled sender and client systems.

Over a period of less than a decade after its inception, the complex systems transdiscipline—which incorporates fields as diverse as biology, geology, physics, engineering, computer science, economics and sociology—had established itself as an important research area. Some of the techniques employed by the field have been chronicled in popular accounts (e.g., Waldrop, 1992):

- The research problem to be addressed was defined as identifying and understanding emergent behaviors of systems that consist on many elements that interact with each other. The early participants further decided that quantitative and algorithmic approaches to defining such systems would be targeted, as opposed to qualitative, interpretive techniques.
- The targeted clients were researchers in other disciplines addressing problems of intractable system behavior, e.g., understanding earthquakes and volcanoes in geology, understanding economic turbulence in business and economics, understanding major climate shifts in climatology, understanding sudden evolutionary transitions in biology, understanding the behavior of cellular automata, neural networks and genetic algorithms in computer science, etc. Because such problems tended to be the most intractable ones in their respective disciplines, the receptivity of researchers to alternative solutions tended to be high.
- The early participants in the field established an umbrella organization, the *Santa Fe Institute*, to help guide the evolution of the field. That institute sponsored conferences as a means of informing new participants. These conferences, in turn, included extensive workshops intended to ensure that participants from very different disciplines became acquainted with the mathematical and algorithmic disciplinary paradigms.
- Participants made an active effort to inform and recruit researchers from many fields who appeared to be examining the types of problems that were the focus of the complex systems transdiscipline
- Individual participants published books that were specifically written to appeal to the general reader (e.g., Kauffman, 1995; Bak, 1996; Gell-Mann, 1994; Prigogine, 1997), and supported journalistic authors in their efforts to catalog the field (e.g. Waldrop, 1992).

As a result of these efforts, the complex system transdiscipline achieved widespread legitimacy as a research area. Moreover, participation in the field further enhanced the prestige and recognition accorded to individual researchers. Much of this can be attributed to the transdiscipline's selection of a set of clients (researchers across related disciplines) with genuine problems to address (understanding the behaviors of systems that were largely intractable) and developing channels appropriate for communicating with these clients (e.g., workshops, books accessible to readers outside of the author's discipline). In addition, through its support of channels intended to resonate with general interest readers, it also helped ensure that institutions would perceive that having ongoing research in complex systems would be a benefit to their own external clientele.

Naturally, there were many additional factors that fueled the success of the complex systems transdiscipline. In establishing credibility, for example, it never hurts to have several Nobel laureates amongst your initial participants. Nonetheless, it is definitely worth noting that many of the activities that contributed to the success of complex systems were never systematically undertaken by the MIS discipline. Among these, identifying a clear client/problem-to-be-solved pairing, actively encouraging the dissemination of research into other disciplines (the very antithesis of judging research success solely in terms of publication counts in a discipline specific set of "elite" journals), and valuing the publication of less technical works (e.g., books) intended to spread knowledge of the discipline to external communities—recognizing that these would, in turn, be valued by the institutions that provided participants with most of their resources. In short, the complex systems transdiscipline paid careful attention to their external clients, and to ensuring that their communications were resonant.

Implications for the Informing Science

The greatest danger that an academic discipline can face is the belief that resonant communications within the discipline are sufficient to justify its existence as an informing system. We have argued that MIS is currently paying the price for such hubris. The informing science transdiscipline, however, is not immune from the same peril. Being younger however, and much less accustomed to free flowing resources—resources that in MIS were unleashed by a tide of students once thought to be inexhaustible—informing science is in a much better position to avoid the trap.

There are a number of general propositions that this chapter has advanced, derived from the use of the informing science framework in analyzing academic informing systems. These include:

- The appropriate research areas for a discipline are best determined by the clients it serves. Continual debates regarding what is and is not appropriate research within the discipline is clear evidence of a shortage of external clients.

- Resonance is the degree to which the information being conveyed is of a form that can cross the sender/client boundary and produce secondary informing activities within the internal client system. If resonance is not present, communications from sender to client will be severely attenuated, if not lost entirely. Without knowing the client, predicting resonant communication forms is impossible.

- The dimensions of rigor and relevance are, by themselves, insufficient to ensure *effective* research. Instead, rigor, relevance *and* resonance must all be achieved if research is to have impact.

- Academic informing systems typically come in disciplinary-institutional pairs, with the former determining research directions and the latter prioritizing resources. These pairs typically share some common elements on both the sender (e.g., faculty, departments) and client (e.g., students, practitioners) side. In the absence strong external clients, individual faculty at research institutions will tend to be drawn towards greater participation in the disciplinary system—which offers great incentives for research success—while departments and colleges will be drawn towards greater participation in the institutional systems, where greater opportunities for advancement in the institutional resource queue are likely to be found.

- A discipline's long term success at a given institution depends upon the degree to which its clients overlap with the institution's clients, since that will tend to determine its priority in the queue for institutional resources.

- A transdiscipline can be described as an informing system that takes a particular problem or scenario and examines it across many disciplines. For this reason, the natural client of informing science is other disciplines. Nonetheless, if it is to survive over the long-term, informing science will still need to find ways of serving clients who are also institutional clients.

If informing science were to look to another transdiscipline as a model for best practices, the study of complex systems would be a good candidate. The two transdisciplines exhibit similarities across several important dimensions. They both were established to study a particular type of system behavior (i.e., emergent behaviors of systems with many interacting components, activities of sender-client pairs). They both employ an institute to help initiate and coordinate disciplinary activities (i.e., Santa Fe Institute, Informing Science Institute). They both welcome participation from a range of disciplines far broader than would normally be encountered in academic circles. They both encourage a broad range of publication types. There are, however, some activities performed by complex systems that informing science has yet to engage in, but might seriously consider emulating:

- *Establishing a catalog of resonant exemplars.* When one thinks of the complex systems discipline, one thinks of Bak's sand piles, Wolfram's cellular automata, Holland's genetic algorithms, Kauffman's fitness topology (with its the pre-Cambrian explosion), along with many other compelling examples. If the informing science transdiscipline is to thrive, it needs its own set of exemplars that both illustrate why it is sensible to study such systems collectively and why there is a pressing need to do so.

- *Educate participants with respect to the nature of informing science.* One of the pitfalls of bringing many disciplines together (as well with being the greatest source of value!) is that each needs to be educated with respect to the frame of reference of the others. At its conferences, the Santa Fe Institute sponsors an extensive series of tutorial workshops intended to instruct participants in the basics, and non-so-basics, of complex systems research. A similar set of workshops should be hosted at InSITE conferences if the transdisciplinary mission is to be accomplished.

- *Encourage more resonant publications.* Relatively few significant advances in complex systems were not accompanied by books or articles that were written so as to stimulate the popular imagination. While such activities tend to produce reactions of disdain amongst many serious academics, they play a particularly important role in a transdiscipline: as the means of communicating findings to those researchers in other disciplines who could never be expected to read anything written in the formal academic prose favored by the disciplines of the original authors. This also means attempting to develop a portfolio of publication types, since what leads to resonance in one discipline may not even make it past the client/sender barrier in another.

- *Place a premium on informing science framework usage outside of Informing Science Institute (ISI) publications.* Editors and reviewers of *InformSciJ* have in the past been advised to encourage authors to submit their best work to that journal. Paradoxically, what is obviously in the best interest of the journal over the short term may be the worst possible advice to give over the long term. If a manuscript is really good, and if it explicitly applies the informing science framework to another discipline, then the *best* place for it would be in a premier disciplinary journal. Acceptance and publication in such an outlet would, all at once: 1) elevate the profile of informing science within that discipline, 2) familiarize researchers considering problems falling under the category of informing systems of the transdiscipline's existence, and 3) provide an example of the transdiscipline informing an external client (in this case, the discipline publishing the research).
- *Become more proactive in identifying potential participants.* A central tenet of the *ISI* family of journals has always been to welcome authors and provide mentoring to all participants. Where additional proactive efforts might pay great dividends is in identifying potential new participants through their research. Towards this end, it might make sense to approach certain authors (of high quality research involving client-sender situations already published in disciplinary outlets) with an invitation to write a revised version of their article for publication in *InformSciJ* or some other appropriate outlet.

These types of activities could help enhance the effectiveness of informing science in delivering its message to a broad set of clients. Such techniques, however, can only be effective if the clients are known. Identifying external clients, we believe, is the essential next step for the transdiscipline. The danger of postponing a systematic effort to identify such clients is that informing science could end up pursuing the same path as MIS. And could be destined to experience what MIS is now experiencing.

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PART II: ELEMENTS OF INFORMING SCIENCE

Chapter 4

Informing Systems for Operations: A Teleological View

Zbigniew J. Gackowski

Introduction

"The fields that comprise the discipline of Informing Science provide their clientele with information in form, format and schedule that maximizes its effectiveness" (Cohen in Chapter 2). Informing should also be ethical and/or efficient. It serves two kinds of purposes: extension of knowledge and conduct of operations. The ultimate purpose of informing, however, is to extend one's control over one's environment, whether physical or social.

Current MIS textbooks are deficient in their coverage of the role of end users and even more so with respect to those who communicate or disseminate information. The texts are overly technology laden, with insufficient and oversimplified coverage of the fundamentals on information, data, and the role of informing in operations. A summary of research published by Huang et al. (1999) supports this statement: "Many best-practice reports witness that information technology alone is not the driver for knowledge management in companies today. Information and knowledge experienced by members of an organization should be the focus, not the system or technology per se.… Technology and systems are facilitators" (p. 4).

Students lack adequate exposure regarding how to examine and analyze information and informing. This is not a task for information technology (IT) personnel, but for information disseminators and clients of informing. To address this gap, a technology-independent inquiry into informing systems is presented. Depending on the situation-specific primary concerns, informing systems need to be examined from the viewpoint of information disseminators and/or information users or clients. The clients' viewpoints are subject to extensive empirical studies within informing science and within the MIT Information Quality Program (MITIQ). The focus of these studies is on information products, services, users' preferences, and requirement specifications. The information disseminators' viewpoints are largely ignored.

This inquiry is presented from the **teleological** perspective on **informing** for **operations,** where the term ***teleology*** refers to the idea that design is driven by **purpose**. ***Operations*** are processes conducted or only controlled by at least semi-autonomously acting humans, their organizations, systems controlled by programs, or artificial intelligence. They may include natural processes. Planned operations are triggered after an analysis of the situation. All human-controlled operations are purposefully developed; hence, the ***teleological perspective*** is an obvious choice. The emphasis is placed on quality requirements related to information use for the sake of effective, ethical, and/or efficient informing within a purpose-focused framework.

After a short examination of the most popular MIS textbooks, this chapter presents an outline of the problems one encounters during examination of informing systems. It also offers some refinements of the Informing Science Framework defined by Cohen (Chapter 2) To facilitate the initial reading, the concepts are presented in a qualitative narrative, employing a level of abstraction that facilitates formal definitions. The latter is necessary to avoid ambiguity of natural languages that might hamper computerization efforts in the light of the fundamental question of computing: "*What can be automated*" (Denning et al., 1989). To complement the narrative, the more formal definitions are numbered and presented in the Appendix to this chapter. For focused reading, key terms in paragraphs are in **bold** font, emphasis is in *italics,* highest emphasis is <u>underlined</u>, and terms followed by a definition are in ***bold italics***.

What do the most popular textbooks say?

No textbook about Management Information Systems (MIS) mentions the art and science of informing. While they may discuss information superficially, the overall process and motivation of information exchange between disseminator and client is ignored. For example, O'Brien (2008), the author of the two most popular textbooks about MIS, as judged by the number of editions, defines *"Information as data* *placed in a meaningful and useful context"* (glossary), and *"Information quality as the degree to which information has content, form, and time characteristics that give it value to specific end users"*. He examines 15 attributes of quality of information within a three-dimensional framework: (1) time, (2) content, and (3) form, with short comments and no reference to informing. He mentions but does not define "information value" and ignores the communicators' perspectives of informing.

In another textbook, Alter (2002) ironically describes "utility value of information" as the fundamental, central, and most pervasive property related to information use by labeling its pragmatic definition as *"more elegant than practical"* (p. 162–168). He distinguishes four factors of information usefulness: quality, accessibility, presentation, and security, which are subdivided into more specific characteristics.

Malaga (2005) suggests considering six aspects of quality of information: accuracy, timeliness, accessibility, engagement, application (relevant), and rarity. Dock and Wetherbe (1988) suggest another six: accessibility, timeliness, relevance, accuracy, verifiability, completeness, and clarity. Both ignore the fact that few of these aspects are intrinsic (naturally belonging) to information; instead, they mainly relate to the use of information. That requirements pertaining to both kinds of aspects are always contextual or situation specific has not been recognized. Thus, a simplistic treatment of information is encouraged by these texts; this treatment in turn encourages a view that informing consists of the mechanical transfer of such information. Such a treatment does not serve students or users well when the real world complexity of such systems is confronted.

Informing Systems – A Teleological View

Basics

In English literature, the first formal definition of informing systems can be found in *"An Approach to Categorization of Information Systems"* (Gackowski, 1982) as follows: "Within the context of Nadler's (1970) terminology on work systems, ***informing systems*** are defined as *"a class of work systems whose* **basic output** *is* **information** *that affects the actions of its recipients."*

The initial framework for informing is based on Cohen's (1999) slightly modified Informing Science Framework:

- **Informing environment** is limited here to **informing entities – source**(s) without the three levels of abstraction about how information is developed, an
- **Information delivery system** that may entail anything from a natural communication channel up to a sophisticated global information system, and a
- **Task completion system – clients** is limited here to **entities informed** engaged in operations or task completion in which information plays a significant role.

Any fragment of reality flexible enough to undergo detectable, replicable state transitions can serve either as an informing entity, entity informed, or both. **Informing entities (sources)** may be active or passive.

- ***Active informing entities*** emit, transmit, disseminate, or broadcast signals conveying information **by nature** or **by design**. Those doing it by nature (e.g., *natural radiation, moon reflects sunshine*, etc.) inform without intent. When by design, they are communicators and/or disseminators that are the main active agents (e.g., *advertisers, preachers, politicians, professional information providers, etc*) who try to affect the entities informed or provide information services for them.
- ***Passive informing entities*** are real objects and processes – passive providers of signals (e.g., *reflection of light, radar beams*) that may yield information in the process of observing, examining, and/or measuring them. Some of the above may be widely known and easily identifiable; others are completely unknown to the entities informed.

Information delivery systems link informing entities with entities informed. They range from simple natural communication channels to sophisticated worldwide information systems. They may be run by informing entities, information delivery providers (e.g., *computing service bureaus*), and/or entities informed. ***Informing*** that is the process that transforms the input signals from the source—informing entities—transmits them to their destination and transforms them into output signals received by and presented to the entities informed—clients. What distinguishes informing from communications is that informing necessarily produces an impact on the client side. The specific nature of that impact remains a topic of discussion. For example, in the original definition, that impact was to be in the form of an effect on recipient action (Gackowski, 1982; Nadler, 1970). Chapter 2, referring to Boland's (1987) "informing as … information is the **in**ward forming of a person that results from an engagement with data," treats it as a process of internalizing data. In Chapter 9, Gill views it in terms of changes to client mental models.

The "inward forming" definition of informing presents a number of serious weaknesses for inquiry into informing for operations. These include the following:

- The definition produces at least as much fuzziness as it resolves:
    - Informing represents a process that is best defined in terms of the distinct changes it produces. If such changes can be purely internal to the client, it will be very hard to measure. The same objection can be raised for a mental-model-based definition.

Information can be defined by a set of distinct quality aspects; presenting it in process terms creates unnecessary ambiguity between the terms information and informing.

- The expression "inward forming" carries with it strong connotations of self-discovery and enlightenment. Unlike education, in routine operations there is not much room for such inward forming of persons.

- Boland (1987) reduced informing to undefined changes within a person; a similar restriction is implied by the mental-model definition. The alternative perspective is that informing is a process widely observed in all nature, particularly that which is organic (e.g., s*eeds, DNA, communication),* even inorganic, (e.g., *crystal forming*), human activities, and in communications with robots. The latter perspective is more in line with the teleological definition of informing since; it is hard to demonstrate that information is used if there is no accompanying evidence of changes. ***Data*** are commonly defined as the given, known, assumed to be true representations of facts; they neither change a situation nor a person. Within the confines of a decision situation, data cannot be a source of information (excluding data mining, which is research) and cannot change the entropy of a system.

- From Shannon and Weaver's (1949) theory of communications, it is known that information measurably changes the state and entropy of the receiver, even of a robot; hence, Boland's approach adds only a new insufficiently defined term.

Except for research with data mining, one cannot gain much by engaging with data, which have already been derived from information; one may use them and to some end present them in different forms for instance for reasons of efficiency. In decision making, data are the building blocks for an initial model.

Informing may be direct or indirect, solicited or unsolicited.

- ***Direct informing*** occurs when signals convey information directly between informing entities and entities informed (e.g., *face-to-face human contacts, direct observation).*
- ***Indirect informing*** occurs with intermediary storing and processing of information. In technologically advanced environments, data are organized in databases or data warehouses run in-house by information providers, client organizations (for themselves), and/or service bureaus. Particularly, indirect informing is vulnerable to interference and manipulation of information.

Entities informed—the one informed—clients, users of information must be, to some degree, autonomously acting entities so that the incoming information may cause them the behave differently than without it (e.g., *marketing prospects, competitors, adversaries, students, voters, the public, etc*). They may also be **active** or **inactive** in the process of informing; they may be simple or composite entities, individuals and/or organizations, even robotic devices controlled numerically by programs or artificial intelligence, and any combination thereof.

The ***active entities informed*** may **actively gather information** from sources, hence be interested in being provided with information products or services. Clients may pay for being informed or seek only information offered seemingly free. They may also to be inclined to enter into a dialog to refine the informing process or refuse to participate in it. Active entities informed gather intelligence about the environment and feedback about the results of their actions.

The ***inactive entities informed*** – clients might be **intentionally targeted** by communicators. Initially, with the inactive entities informed and observed from outside, the effect of informing may not be noticeable for a long time. However, once the latter act, the difference may become significant as the fruits of upbringing, education, training, indoctrination, or simply programming.

The design and examination of informing systems differs considerably for active and passive informing. Informing is always purposive, thus biased by purpose. From the perspective of entities informed a broad spectrum of all kinds of **misinformation** flows through communication channels and information delivery systems. Misinformation lies between two extreme exceptions: **disinformation** and **valid information**.

From the perspective of communicators, one may distinguish perfect communication, effective communication, miscommunication, and discommunication. In active informing by design, communicators try to influence the behavior of the targeted entity. Communicators affect the behavior of many clients; hence, their perspective carries more weight than the clients' perspectives. Tudjman and Mikelic (2003) emphasized examination of informing also from the sender's viewpoint.

Human-controlled informing entities and entities informed expect measurable or at least perceivable results of some utility value. Hence, in cost-aware environments where one aims at the best results, one should carefully examine effectiveness and efficiency of informing systems. **Schema 1 Informing** visually summarizes all of the above aspects of informing.

Schema 1 Informing

There are ***universal conditions for effective informing*** if informing is not defined as "inward-forming of a person" (Boland, 1987) by data, which are commonly interpreted as the already given, available, known, and reliable representations of facts. When one does not know them, they should become informed from whatever reliable source, but then we deal again with information about unknown (from the perspective of entities informed) facts.

Schema 1. Informing

Informing Entities – Information sources					
Passive	**Active**				
	By nature	**By design – on purpose**			
		Source known		**Source unknown**	
(Reality observed)	(Emit signals)	**Informing** **Enforced**	**Informing** **Not enforced**	**Identifiable**	**Unidentifiable**
		(Mandat. Edu.) Bias	(Media) bias	Bias	High risk of disinformation

Quality problems in collecting, acquiring, and recognizing information

Indirect informing

Direct informing

Transmission Problems

Information Delivery Systems
(intermediary databases and data warehouses)

& network quality problems

Indirect informing

Quality problems with presentation of information

Entities informed – clients, users (Autonomously functioning individuals, organizations, robots, targeted and/or seeking information)	
Inactive	**Active**
(Not yet acting)	(conducting operations – high risk of disinformation)

Quality problems with further use of the information

Sufficient Conditions for Effective Informing Resonance

There are ***universally necessary conditions for effective informing resonance are*:**

1. There must be an initial difference in states between informing entities and entities informed. In communication theory (Shannon & Weaver, 1949) the difference is measured by entropy.
2. Some of those states must be corresponding or equivalent states within similar ranges of states to make resonance possible between them. The concept of informing resonance was proposed by Gill (Chapter 9), but applied only to human mental models. It is a universal phenomenon whether we deal with mechanical, electromagnetic, molecular, or mental entities and their models. When entities resonate, they communicate, not necessarily effectively yet.
3. If equalization and/or synchronization of states occurred, a communication took place, a state transition within the entity informed (its physical, formal, or mental model) has been triggered, the entropy of the communication system changed, thus the received communication has been recognized and was not available or known before, otherwise it overlaps with what is already available to the entity informed.

4. However to become operationally effective, the received communication must be internalized as situation-specifically, actually or potentially ***actionable data and/or elements of knowledge*** qualified to update databases and knowledge bases, otherwise the communication is ***irrelevant.*** Nevertheless, it might have been relevant, but was only handled otherwise. Thus for informing to be effective the communication must resonate with the receiving, decision-making, and action executing mechanisms. They have their human equivalents of those who as a single individual or, with division of labor, those individuals who were in charge of receiving the communication, making decision, and executing it, as it occurs in complex organizations. If a communication fails to resonate at any of the intermediary stages of operational informing, informing is ineffective.

Boundaries of Informing and its Nature

What the triggered state transition will cause depends exclusively on the reality (the system of operations and its environment) of the entity informed. What it does, what the consequences will be, and how the decision maker will handle the change is not the subject of informing; it depends on the situation and how the operations are structured, controlled, and managed. Informing for operations and operations are two separate but intersecting issues. This distinction defines the ***spatial and temporal boundaries of informing***:

The **entry and exit points** of the informing process, where it intersects with reality that is subject of other disciplines; and

The **moments** when the informing process starts and terminates, while the processes in the intersecting domain may continue.

Communications that resonate with possible states of informing entities may trigger a state transition as simple as a binary signal (on, off), a value (number, word, code, password, etc.), a text message, map, picture, etc.; it also may trigger a single or a series of discrete state transitions—one at a time with serial transmission or a group of state transitions occurring with parallel transmission. Even a complete replacement of all the data available to the entity informed may take place (*memory upload, brain wash*).

On the one hand, whatever the subsequent state transitions will be, whatever the **entity informed** (*device, robot, trained animal, or human*) **does** is subject to process control, animal training, education, propaganda, psychology, sociology, political sciences, etc. but not informing per se, which demonstrates the ***interdisciplinary nature of informing***. On the other hand, **informing for operations or extension of knowledge** is omnipresent in all disciplines, which demonstrates the ***transdisciplinary nature of informing***.

In operations management, informing makes sense only as much as it eventually impacts actions and, subsequently, their results, immediately or with delay. To become **effective,** information or elements of knowledge must become operationally **usable** (*operationally recognized, relevant, meaningful, significantly material, timely and spatially available, actionably credible, and meeting other situation-specific necessary primary use requirements*, if any. Then, if, in addition, they are also **effectively operationally complete and engaged** in operations, the usable information may actually become **useful** (Gackowski, 2005b) by triggering, modifying, or ceasing action. Otherwise, the information may potentially be only an ***indirectly useful factor in waiting***.

From the perspective of entities informed, after informing took place, the gathered (collected, acquired, and recognized) information values become the operating entities' **data values** and recognized **elements of knowledge,** which update common databases and knowledge bases. Examination of informing for operations occurs within a defined frame of reference.

The Purpose-Focused Framework for Examining Informing

The purpose-focused framework (Gackowski, 2004a) for the inquiry into informing systems takes the operations-management approach and views it through the lens of the decision situations it serves. One assumes that:

> a relatively complete qualitative cause/effect diagram, known as a fishbone diagram, can be drawn. It identifies the major factors that affect the expected results, the situation itself, and/or the required steps to implement the decisions made. Based on the available knowledge, the entities informed make decisions and subsequently act if deemed beneficial. The results of operations can be assessed by the informing entity in active informing or by the entity informed in passive informing, or both.
>
> an analysis can reveal the relative strength of each factor by its impact on the main purpose. Various criteria are used to measure the main purpose of operations (e.g., *net income after taxes, retained earnings, return on investment, return on equity, funds raised, patients healed, saved lives, etc.*)
>
> one can develop an informational model of the decision situation under consideration by taking inventory of what is already known and what is unavailable—still to be acquired; that what is known, given, or available constitutes the **data component** of the model. Anything that is not yet available but must be acquired by proper intelligence or communicated (sent, disseminated, or broadcasted) constitutes the **informational component** of the model.

The ***data component*** of the model symbolically represents what is already known (*objects, events, and their states*) about the situation. The ***informational component*** symbolically represents what is not yet known or what is uncertain about the situation, what must be acquired, gathered, measured, counted, etc. Only information may change the **results** and/or the **decision situation** by itself and/or the **actions** to implement the decisions made.

The ***main function of informing processes*** is to move the necessary information from its source to its target. Here, the ***main purpose of informing*** is to contribute to the main purpose of operations. Those contributions or payoffs, as defined by Marschak and Miasawa (1968), are functions of the informing systems deployed. In sound environments, informing systems should also be **ethical** and/or **efficient**. When the generated effects do not significantly exceed the incurred cost, there is no sound economic reason for such projects. The ***ultimate purpose of informing*** is to extend or maintain one's control over one's environment, physical and social, or to predict the behavior of that environment so as to improve one's performance of a particular operation.

The criteria of what constitutes an acceptable level of effectiveness or efficiency must be determined within the context of the organizational environment. There are always many requirements and constraints imposed on any project. All of the above should be articulated in formal project requests or requests for proposal for the respective informing systems. Good project requests should specify (1) the entities' main objectives, expressed in terms of observable; better yet, measurable effects to be attained for the common purpose; (2) requirements and constraints; if possible, only those externally imposed on the project; (3) time and spatial boundaries of the informing system and the project; and (4) evaluation guidelines of the project.

Quality and Use-Related Requirements of Information

The initial definitions of quality are general. They are based on the Aristotelian approach to quality as something that enables one to distinguish and define objects. Next, they will be expanded to accommodate the aspects useful in operations. Generally,

- ***quality*** is an infinite multidimensional **space of quality dimensions** or attributes of essential and distinctive characteristics called ***quality aspects*** (see Appendix, Definition 1).

- ***distinguishing quality*** of a class of factors (e.g., *cutting tools*—factors of substance, *aerial pictures*—factors in form) is a finite multidimensional space of the **necessary quality aspects** (e.g., *length*—cutting edge, *number of dots per inch*—resolution of a picture) (see Appendix, Definition 2). Necessary distinguishing quality aspects of factors facilitate compression of knowledge.
- ***quality of a specific factor*** (e.g., *tool, data value*) is defined by its properties—states of quality aspects (e.g., *operational* or *non-operational* for a device, *usable or not* for a data value) of its **necessary** (e.g., *sharpness* of a tool, *credibility* of a data value) and **other** (e.g., *acquisition cost*) properties (see Appendix, Definition 3). A quality aspect can take on one out of two or more distinct states—properties; it can be Boolean {true, false}, enumerated, or a set of numbers. The last implies measurability and ranking of states (e.g., by *size* or *caliber of firearms*).

quality requirements (e.g., *type, size, color, cost,* etc.) for a specific instance or class of entities are defined by the required states—required properties of respective quality aspects (see Appendix, Definition 4).

Two distinctively different requirements (always contextual and situation-specific) are related to factors in form used in operations that pertain to aspects of quality:

Intrinsic (naturally belonging) to them such as ambiguity; accuracy; precision; currency; cardinality of their granularity (fidelity, resolution, definition), which immediately determines the maximum amount of information necessary to communicate them; form of representation; etc.

Intrinsic to their use in a specific situation described by the model, such as operationally recognizable, relevant, of meaning, significantly material, available timely and on site, actionable credibility, usability, usefulness, etc.

Properties of factors acquire their materiality from the **situation** (purpose, circumstances, and adopted criterion of effectiveness) to which they apply, while a **factor** acquires its materiality from its **properties—**states of its quality aspects. In addition, factors must meet adequate **use requirements** determined by the situation. One assumes that

- ***materiality of a specific factor*** is a function of all of its properties (see Appendix, Assumption 1), and
- ***changes of materiality of most properties of factors' aspects of quality*** are subject to the law of ***diminishing returns*** (Encyclopaedia Britannica, 2007); hence, each quality of each factor should be used at its optimum or acceptable level. It implies that, for most quality aspects, the subsequent improvements do not monotonically improve effectiveness or efficiency of operations (see Appendix, Assumption 2).

Significant operational quality of a factor is defined by significant properties of its significant quality aspects, which qualify the factor to play a significant role in operations. Generally, it can be represented as a vector of significant properties of all dimensions in its quality space (see Appendix, Definition 5).

The ***state*** (not a measure) ***of quality of operations*** is defined by a set of vectors of significant properties with regard to all significant quality aspects of respective significant factors with regard to the purpose, defined threshold of significance, and significant states of nature; it is an ordered septet of the (1) measure of the operation results, (2) purpose of operations, (3) threshold of significance expressed as the smallest increment of the measure of results, (4) set of significant factors, (5) sets of significant quality aspects of significant factors, (6) sets of vectors of significant properties of significant quality aspects of significant factors, and (7) set of significant states of nature (beyond the decision-makers' control) (see Appendix, Definition 6).

The goal is to obtain the optimal or acceptable results of routine operations assessed by the selected metric. Quality requirements can be at their optimum, acceptable but suboptimal or unacceptable level, even left undefined. One can measure quality of operations indirectly by its impact on results, not by the properties of operation factors as practiced in empirical studies and industrial applications of Total Quality Management (TQM).

Thus, in operations, significant properties of significant quality aspects of significant factors are at their ***optimal*** or ***acceptable level*** when the **results are optimal or acceptable**. In other words, when the results of operations are **optimal or acceptable**, the vector of all significant properties of all significant factors defines by enumeration the ***optimal or acceptable state of quality of operations*** (see Appendix, Definitions 8 and 9).

In operations, properties of factors acquire relevance, meaning, significant materiality (importance), or utility value from the purpose and circumstances of operations in the light of the adopted criteria of effectiveness, ethics, and/or efficiency (see Appendix, Assumption 7). This occurs only when a factor becomes a subject of interest, the bone of contention of competing decision makers, who perceive it as relevant, meaningful, and significantly material for their endeavours. While following their perception, they project their power, which manifests itself as a "force field." It is always of limited significant range, radius, or sphere; it entails the physical, political, and economic forces in society, business, administration, or military operations.

Significant materiality of an entity is established when it becomes the center of intersecting forces in an equilibrium of demand and supply exerted by competing participants. It results in a kind of price tag, not necessarily in monetary terms, of the contested entity until equilibrium becomes established at a different level. Properties of factors are of no utility value on their own merit when not subject to such forces.

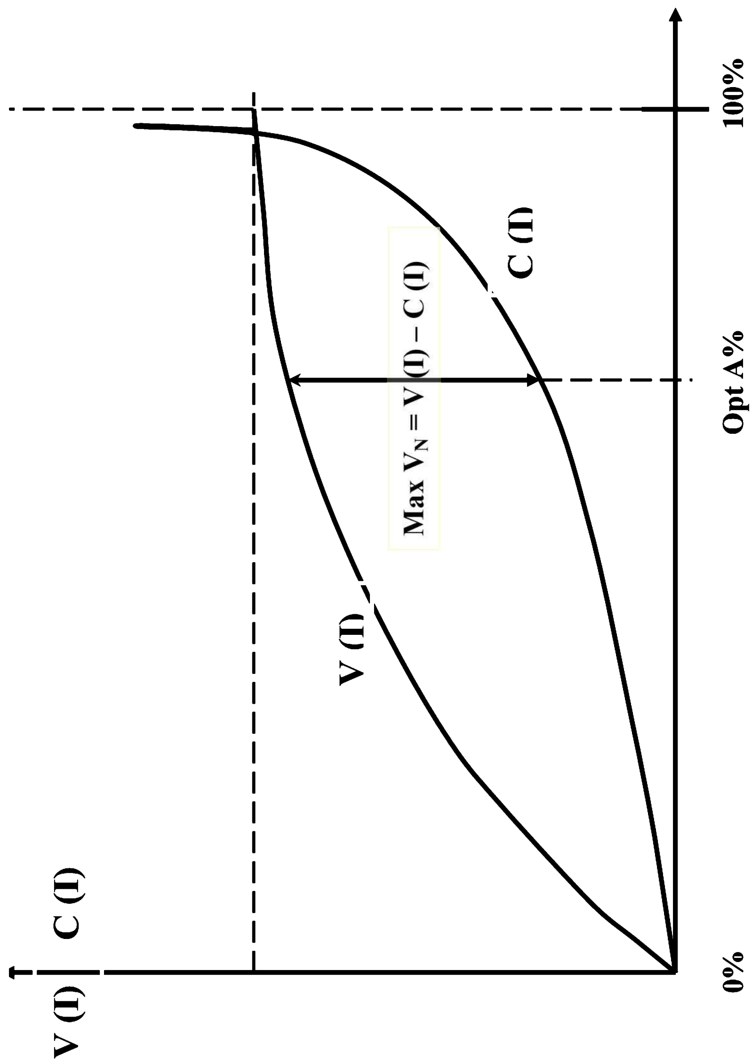
Materiality of Properties: the Law of Diminishing Returns

Schema 2 graphically illustrates approximately the situation-specific materiality of the state transition triggered by the incoming information changes when its accuracy or **precision** change in percentage points is within the range [1 - 100%]).

Schema 2

The first line represents the situation-specific **utility value V(I)** of the state transition triggered by the incoming **information I** as a function of the degree of its **accuracy A** that is **V(I) = Φ(A).** One assumes that its utility value equals zero if the accuracy of information is zero. First, the line rises relatively fast, and then with increasing accuracy slows down until it reaches its final value. Before the end of the range, consecutive increases in accuracy yield a lesser and lesser marginal increase in its utility value. It reminds of logarithmic functions.

The second line represents the situation-specific **procurement cost C(I)** of the **information I** as a function of the degree of its **accuracy A** that is **C(I) = Φ(A).** One assumes that zero accuracy costs zero. First, the line rises slowly with increasing accuracy and then accelerates. Before the end of the range, it enters into an asymptotical ascend. Accuracy or precision of 100% is unattainable. The procurement cost



Schema 2 Optimum level of Accuracy A as function of Net utility Value V_N of information I

rises steeper and steeper to become *prohibitively high*. Higher levels of accuracy require end users to incur ever higher costs of research, measurements, additional observations, expensive instruments, etc.

Before reaching 100% accuracy, both lines intersect. In contrast to lay perceptions, one never gets rich or enriches others while incurring costs equal to the value of results. The optimum degree of accuracy lies where both lines are the furthest apart. There, the ***net utility value of the effect caused by information V_N (I)*** reaches its maximum. *Maximum benefits* indicate the *optimum degree of accuracy*. The graph approximates the law of diminishing returns of indiscriminately improving most quality aspects.

It is an important law but not a universal one. In networks in general, the marginal cost of adding another participant is negligible, while the marginal gain is larger. The more subscribers there are to a telephone system, intranet, or Internet, the grater its value is to all subscribers; each of them can interact with more subscribers. The utility value of the nth participant in a collaboration network is unknown and certainly not necessarily less valuable. **Network economics** differs from **conventional economics** of factors.

Measuring Quality: Degree of Requirements Compliance

Many ask how to measure quality. Such a question implies that (a) a metric of quality can be developed, (b) it may be useful, and (c) the more quality the better. The answer to this question is surprising in the light of the amount of effort, time, and resources spent on developing metrics of quality.

With a well-defined point of reference, a frame of reference, a yardstick, and well-defined distinctions about quality, one may embark on an examination of how generally use requirements of factors may impact operations and whether some requirements are valid in all situations, hence universal.

The first step is to operationalize the commonly used term, quality. In operations, a state of their quality is a set of vectors of significant properties (states), within the multidimensional space of quality aspects of all significant factors (see Chapter 10, Appendix, Definition 6). Initially, it may be the 179+ potential quality aspects identified by Wang and Strong in (1996).

According to the postulate of teleological perspectivism and relativity, the materiality of properties and their attributed factors are determined by the situation-specific purpose and circumstances of the operations, hence relative only to them. It affects their materiality analogously to a force field that affects mass of matter in physics. It implies individuality of properties. The results of operations are determined by the situation-specific combination of factors that acquire materiality from the circumstances of operations. Thus, any direct, general (transcending specific situations), and **compound measure** of quality is impossible; it renders such attempts futile, subjective, and arbitrary as long one does not find something in common in them.

Within each quality aspect, its states are measured or ranked in its own way, and those aspects are interdependent (Gackowski, 2004). Whatever their number and their measures are, no exchange or trade-off rates are available and unlikely to ever be. Hence, they cannot be reduced to a common scalar value and, as such, they *cannot be summarily measured directly.*

In operations, the impact of factors, whether in substance or in form, is subject to at least **eight** universal use requirements and some others that are task specific. There may also be many necessary secondary requirements imposed by ethics and economy. Trade-off between necessary requirements is impossible. They must always be met; hence, their ranking is precluded despite attempts in this direction (Wang & Strong, 1996). They may be ranked by their strength as prerequisites and the ease or difficulty of their examination, never by their relative importance.

What purpose may a composite measure of quality serve? To reduce the problem ad absurdum, let's assume that trade-offs among properties of quality aspects are possible, and a composite measure of quality can be calculated. Results of operations, especially their cost effectiveness, are functions of individual properties—states of specific quality aspects of the impact exerted by specific factors but not groups thereof. Intuitively, many think that improved quality of any factor improves the results of operations. It may or not. While improving on any single quality aspect, at first it may tangibly improve results of operation, but later the additional marginal return may become negative (see Schema 2 and examples in Gackowski, 2004), when the additional (marginal) cost becomes prohibitively high. This holds true in any economy. When, only with a few exceptions, improvements on most quality aspects do not *monotonically improve effectiveness of operations, the same holds true of their composite measure.* For the best results of operations, the significant properties of the impact-of-operation factors must be applied at their optimum or at least acceptable or satisfactory levels. Unchecked efforts to improve quality in all aspects are counter productive. The law of diminishing returns applies in economy with full force. No aspect of quality should become an end on its own. Each quality aspect should be fine tuned from the perspective of maximized results of operations.

One may summarize the above as follows: ***Direct compound metrics of any group of quality aspects are objectively impossible and useless.*** By the law of teleological perspectivism and relativity, all assessments, including assessments of impact of factors on operations,

- are always situation-specific, not universal,
- measured differently within most quality aspects.
- of binary nature; hence not subject to ranking by importance,
- with no exchange trade-offs,
- of only **situation-specific** materiality, thus impossible to generalize, and
- with only a few exceptions, **never monotonically affect** the results of operations due to the law of **diminishing returns** (2007) on improved quality of each aspect.

Thus, any direct compound metric of any group of properties has to be arbitrary, impossible, and useless. One may, however, test, for instance, by simulation, the impact (on operation results) of changes to individual properties. Properties should be fine tuned within each quality dimension from the perspective of maximized results of operations.

In 2005, Oliviera et al. (2005) presented **"*A formal definition of data quality problems,*"** limited it to database perspectives, left untouched the management perspective, ignored other limitations of their approach, and took an exclusively <u>internal</u> view of quality problems. They assume, "let *u(t,a)* be the <u>correct</u> and <u>updated</u> value that the attribute *a* of tuple *t* was supposed to have" (p. 17, emphasis added). Managers rarely enjoy such a luxury. Correct values are better than incorrect, but, still, they may be useless. The authors do not test whether the data values were ever used and, when used, whether they were useful at all. Neither "correct" nor "updated" were defined, while one knows well that there are no formal, logical, or computational ways of assuring correctness and currency of data values in general. Oliviera et al. ignore that data meeting all the identified 29 quality criteria are only uncorrupted values, regardless of their operational quality. The presented definitions are useful for cleansing databases from gross corruptions and for testing how error-prone database systems are in their design and manipulation of initial values. To the above extent, the study indeed appears to be complete. The proposed criteria facilitate testing the database design and operations by detection of distortions inflicted on sets of input test data.

To this end, even operationally useless fictitious data suffice. In addition, when using a set of only *incorrect* test input data (useless for practical applications); one may discover how sturdy, resilient, and tight the defenses of the database systems are in their design and routine operations. Both tests measure how flawless the design and operations of a functioning database system are but nothing more. The rarely-to-never attainable goal is zero defects, zero corruption, or 100% perfection. Because its degree can be measured, it is mistakenly taken for measuring data quality. It does not measure how the manipulated data that populate the database qualify for use in operations. Certainly, the more corrupted they are, the less they qualify for use. One can easily measure the degree of how all the intermediary mechanisms, including databases, corrupt the initial data values using test data values that are of zero quality for real-world operations. This measure does not depend on the operations quality of data. It measures only the degree of corruption of any data stored in databases.

There is some limited rationale for it. When one takes a limited view of quality, one may argue as follows. Storing data values in databases implies they are deemed useful. If corrupted, they are less useful, useless, or even hazardous. Under special circumstances, they may become a liability of deadly consequences (Fisher et al., 2006, p. 5). Certainly, this limited approach to data quality may and statistically does produce some worthy immediate improvements in organizations, but it does not address the core issue of quality from the operations management perspective that offers answers of universal validity.

Thus, a general direct composite measure of quality is unattainable. We need a distinction between the quality of factors used in operations and the degree by which they were later corrupted while manipulated. The first one is of management's concern. The second one is of concern for designers and operators of information systems and for managers who deal with routine operations. They may not be aware of the implications of these corruptions.

We also need a broader strategic view of quality. The materiality of factors is ultimately determined by the strategic concept of operations. In business, it is embodied in a business plan. It provides the framework for interpreting reality and assessing the significance of the impact of its different aspects. These aspects lend importance and materiality to any representation (information, data, and rules of reasoning and proceeding). This materiality again pervasively lends its weight to all aspects of use requirements that pertain to the representations of the factors under consideration. However, the external view of quality at a higher level offers an indirect solution to the irresolvable problem of a direct composite measure of quality at its base level.

In summary, with relative ease, one can measure the impact of any use requirement on operations, particularly by simulation. It can be summarized as follows:

- For factors to make a significant impact on operations, those factors must meet certain use requirements that will be discussed later.
- As long as operations serve a measurable purpose with quantifiable increments of purpose or its effectiveness as functions of the properties of the factors used, one can assess the impact of their changes.
- The grand total of the increments account summarily for all changes of properties, thus indirectly measure the changes summarily.
- **situation-specific**, **indirect,** nevertheless **composite** measure of factors' quality; however, it can be neither general nor direct.

Any handling of factors in form before their use may introduce errors (of any kind); it rarely improves and mostly corrupts them. Such problems are mostly of a technical and low routine nature. Any chain is as strong as its weakest link. The materiality associated with a chain is determined by its weakest link, the ultimate purpose of use, and where it is anchored. In the realm of information, it means on which information sources it relies. When no redundancy and no contingency provisions are built into a system or network of such chains, an intermediary link that fails ruins their design and operation.

How Informing Affects Operations?

Informing defined from the praxiological perspective is the science and art of practical endeavors to increase its effectiveness, ethics, and/or efficiency. This study focuses on informing for operations. The fundamental underlying question is what and how informing can contribute to operations. It is an inquiry into the mechanism of how informing affects operations. Effectiveness, ethics, and/or efficiency of operations are situation-specific functions of the utility of contributing factors. The focus is on factors in form (information, data, and other elements of knowledge) and their use requirements.

Wang and Strong's (1996) empirical survey-based study, *"Beyond Accuracy: What data quality means to data consumers,"* in its first stage identified a plethora of 179 dimensions of data quality. At first, this multidimensional quality space appears chaotic. Can quality aspects be classed and ordered? Where there is a problem, there also is an opportunity—a dialectic unity of the opposites. To this end, we need a defined perspective with a point and frame of reference, an evaluation criterion, and a yardstick, as defined in the previous chapter. The teleological perspectivism and relativity of assessments offers the key.

In operations, for factors to play a role, they must meet many use requirements. In planning and designing quality informing systems for operations, we need a qualitative analysis of requirements for significant operations factors: how they contribute to effective, ethical, and/or efficient informing that should be assessed the same way. One can discern four distinct ***levels of expectations.*** Operations may be:

1. **effective** only, which characterizes operations conducted with an all-out effort, at any cost, regardless of other consequences, sometimes out of desperation or emotions, sometimes as heroic acts of determination in special operations and even suicidal terror acts.

2. **effective and ethical** when collateral consequences of operations are taken into account (e.g., civilian casualties),
3. **efficient,** thus by default, effective, however conducted economically with regard to the incurred cost, outlays, and expenditures at an acceptable level of the efficiency ratio - effects divided by inputs, and finally,
4. **ethical and efficient** when meeting additional ethical requirements (e.g., less hazardous to consumers' health, within or above legally acceptable limits, etc.)

Some of the requirements pertain to quality aspects intrinsic to contributing factors that are situation independent, while the rest pertains to their use in specific situations and its model. Nevertheless, all requirements are always **situation specific**. When it comes to factors in form—data/information—there are only very few quality aspects that are intrinsic to them, such as accuracy or precision, that can be assessed and measured independently of the situation in which they are used; nevertheless, respective use requirements still remain situation-specific. Requirements analysis calls for answering at least some of the following fundamental questions:

1. Which of them affect operations **directly** or **indirectly?**
2. Which are **necessary** or only **desirable** to meet?
3. Which of the necessary are **primary** or **secondary?**
4. Which of the primary are **universally necessary** or **other** only **situation-specific necessary?**
5. Which of the above affect operations **qualitatively** or <u>mainly</u> **quantitatively?**
6. In what **order** should the above be examined or tested?
7. Which of them are of **stronger** or **lesser impact** and **by how much**?

When factors, their quality aspects, and properties change, the entire situation may change. It is useful to distinguish the following degrees of changes listed in descending order of scope of their impact:

The model of the situation, the way the decisions made, are implemented, and the results of operations according to the adopted measure.

The model remains unchanged; however, the changes affect the way decisions are implemented and the results of operations.

The model and the way decisions are implemented remain unchanged; only the results of operations change. This is the lowest degree of change that only quantitatively affects results.

Directly means that changes to requirements directly affect the results of operations, the decision situation, and/or the way decisions are implemented. ***Indirectly*** means that change to use requirements contribute only to states of quality of a higher order factor or a direct one, thus indirectly impact operations to any degree mentioned above. ***Necessary*** use requirements are **mandatory** and, as such, are **prerequisites** for further examination of the affected factor. They are of the highest importance and exactly of the same consequences; if not met, they make the factor unacceptable for operations. The necessary ones may be primary or secondary.

- ***Primary use requirements*** are those necessary use requirements that are determined by the nature of the situation, thus **objectively independent** of the decision maker.
- ***Secondary use requirements*** can be, at least to some degree, controlled and manipulated, whether legally or not, by the chief executive decision maker; thus to some degree, they actually are **dependent requirements**. They pertain to ethics and efficiency of operations.

Some of the necessary requirements are always, hence ***universally necessary***, while the remaining ones are only ***other situation-specific necessary requirements***. Individual factors should be examined and tested first to assure their ***usability*** at some of the previously defined **levels of expectation**. The jointly met necessary use requirements constitute a **sufficient** reason that makes a factor ***usable;*** they always <u>qualitatively</u> and <u>quantitatively</u> change the decision situation.

Changes to a use requirement that subsequently requires at least a **partial redefinition of the decision situation** (e.g., that add or delete a column or a row from the decision-situation matrices - Table 2) are ***qualitative changes.*** Changes to a use requirement that subsequently only **quantitatively affects the results of operations, the decision situation, and/or the way decisions are implemented** are ***quantitative changes***. ***Mainly*** means here that a use requirement that quantitatively affects operations does not exceed its acceptable limits (e.g., *limits for driving under influence*) or reach other critical states (e.g., *melting, freezing, and evaporating*) that then may also trigger qualitative changes.

Among the universally necessary requirements, there is only one situation-specific use aspect that adequately measures the scope of a factor's impact on operations. This is its **materiality**, utility value, or payoff; otherwise, impact analysis would not be possible. Materiality is a fundamental, central, and most pervasive use aspect. If of sufficient value or materiality, it determines significance of each factor by providing a sufficient reason for its further consideration; it orders, ranks, and prioritizes them and lends importance to their respective companion factors in operations. Operation factors, including their quality aspects, properties, and use requirements can be partially (asymmetric, transitive) ordered by their materiality.

Requirements may affect operations directly or indirectly via respective direct factors. The latter should also be examined in an economical sequence. Each subclass of requirements may require a different approach to ordering its elements. The necessary requirements, despite the fact that they are of the same ultimate consequences, should first be ordered by their strength as prerequisites. The number of necessary requirements that need not be tested, if a prerequisite requirement is not met, measures its ***strength as a prerequisite***. Increasing difficulty of testing should again rank those of equal strength as prerequisites. The ordering can be attained by pair-wise comparison of the requirements. The indirect requirements are again naturally ordered by the **level of** their **indirectness** measured by **one plus the number of intermediaries** between the examined indirect requirements and the affected entity that directly affects operations. This additionally orders the indirect factors, which may be of the first, second, and subsequent orders. Jointly, members of each subclass of use requirements can be ordered by at least two criteria: their materiality and some other applicable criteria. Thus, one may posit that, jointly, all use requirements **satisfy** the **axiom of choice** (2008) in the theory of sets and assure that in most cases those requirements are ***well-ordered sets***.

For operations, usable factors must be **actionable** so that one may act on them. To this end, they must be operationally effectively complete with regard to the task to be performed. Once they are complete, they can be actually applied, employed, or engaged in operations and thus become ***directly useful*** or only ***indirectly useful***. Those indirectly useful are on standby at different levels of readiness or only retained for potential engagement as ***resources in waiting.*** Any of them can be ***sufficiently useful*** at any of the **four levels of expectations,** defined before (see Appendix, Definition 19).

Operation factors to be usable, actionable, and useful must meet many necessary (primary and secondary) use requirements that are the focus of the following section.

Requirements Related to Factors in Form

Necessary Primary Use Requirements

Factors in form (data, information, or elements of knowledge) must first be usable (also denoted *"fit for use"*). To this end, each of them must meet the necessary primary use requirements: (1) operationally recognizable, (2) operationally relevant, (3) of operational meaning, (4) operationally significantly material, (5) operationally timely available, (6) operationally on-site available, (7) actionably credible, and (8) conformable to all other applicable situation-specific necessary use requirements. The first seven are universally necessary. With expectations higher than mere effectiveness of operations, a factor in form must also meet the secondary use requirements for ethical and/or efficient operations. The secondary necessary requirements will be discussed later. The necessity of these requirements is easier to comprehend when one compares examination of factors conducted for the first time versus their routine examination for routine operations. Examination of new, unknown factors in form offers more insight. Where possible, the universal use requirements have been operationally defined using the concepts and operators of the set theory.

Whether they are met is always contextual and situation-specific. In common use, they all are attributed to factors in form, while none of them is intrinsic to them; they are functions of the situation of operations. Hence, the term information quality is a shortcut, while actually they are function of the situation. For instance, materiality of a factor in form is the operational consequence of the state transition in the model, not a property of a data or information value, but its situation-specific use. The reader should keep these remarks in mind while reading the following definitions.

Operationally recognized

The representation of an operation factor must first be recognized by the using entity via its receptors. Never a single value, but always a group of them, can sufficiently represent a factor (e.g., *temperature in degrees of Fahrenheit, Celsius, and Kelvin* requires a number, and location and time of reading). A representation to be situation-specifically ***operationally recognized*** must match some elements of knowledge familiar to the entity informed or some corresponding states of the robotic device being informed (see Appendix, Definition 10).

This is the *first* universally necessary, primary, and prerequisite use requirement for further examination of the consequences the recognized factor may cause in operations. When, for any reasons, the entity informed (also a receiving device) is unable to recognize an information item, it must be excluded from further examination, at least for practical applications; it may remain subject to research. If a factor in form is irreplaceable or indispensable, it directly quantitatively affects operations with regard to the situation, implementation, and/or results of operation. Recognition is contextual; a more educated entity informed, user, client, a conditioned or trained one, or a different receptor under different conditions might still be able to recognize it. The signals carrying information must be noticeable to senses or sensors, discernible, or identifiable. Recognizeability of information is of concern for users and disseminators. It plays a role, but in a different way, during acquisition of information from a source and during presentation of information to the users in indirect informing.

Communicators and disseminators face more complex challenges than entities informed. A plethora of factors comes into play here. Many of them are of a subtle psychological nature concerning how to effectively reach the targeted entity and stimulate a desirable resonance in it (see Chapter 9) by employing the findings, skills, and tricks offered by the art of communications, rhetoric, marketing, advertising, etc, which intersect here. The recognized entity should be operationally relevant; otherwise, discontinue its examination.

Operationally relevant

In routine operations, a recognized entity, to be situation-specifically ***operationally relevant,*** must match some factors actually used in operations. If a formal or only a mental a model of operations exists, one may test whether it matches any of the model's variables. This is the *second* universally necessary, primary, and prerequisite use requirement for examining other requirements for the factor (see Appendix, Definitions 11a & b). In operations, a relevant factor should have at least some operational meaning; otherwise, discontinue its examination.

Of operational meaning

An operationally relevant factor must also have at least some operational meaning; that is, it must make a difference in the situation. It should yield a non-zero difference, if represented by a single value or a non-empty set of differences, between the current outcomes that account for the factor and the previous outcomes of the situation without the examined factor, as viewed by Pierce (1958), the father of verifiability theory of the meaning (see Appendix, Definition 12). This is the *third* universally necessary, primary, and prerequisite use requirement (required property) for examining the other requirements for the factor. Such a factor should also be of significant materiality; otherwise, discontinue its examination.

Significantly material—
the fundamental, central, and most pervasive requirement

For effective operations, only factors of ***significant materiality*** count: when there is a significant difference in results of operations when one acts with and without the factor in form. This is the *fourth* universally necessary, primary, and prerequisite requirement for examining other requirements for the factor; if not met, it renders the factor negligible in further considerations (see Appendix, Definition 13).

Materiality ranks each factor f relatively to the sum of absolute | | materiality M(f) of all factors in their set F:

$$\textbf{\textit{Rank (f)}} = \mathbf{M(f)} \;/\; \sum |\mathbf{M(f)}| \text{ over all f 0 F} \qquad (1)$$

Within the class of significant factors F, one must distinguish two disjoint subsets of them: factors directly adding value to the results of operations and factors of indirect impact. The latter are indispensable for effective use of the previous ones. They may be called "necessary companion factors" (e.g., *location and time*) of factors adding value to operation results. Thus, they also significantly impact the operations. For instance, emergency calls for roadside assistance, which add a well-defined value to operation results, must be accompanied by information values about the location and some indispensable equipment or tools (necessary companions in substance) to provide the service; otherwise, such calls might not be effectively handled.

Generally, **significant materiality** is a unique universally necessary primary use requirement, because it is:

- ***fundamental*** as the only one that provides each factor with a **sufficient reason** to be **considered for operations**;
- ***central*** in all considerations about **effectiveness** and **efficiency** of operations, because it partially (asymmetric, transitive) ranks or orders all significant entities, whether factors, quality aspects, and/or properties,
- the most ***pervasive*** because it **determines the materiality** of the remaining **necessary requirements** of the factor, its **necessary companion factors,** and, to a lesser degree its **indirect factors.**

A significant factor should also be available; otherwise, discontinue examination.

Operationally timely and on-site available

A significant factor should also be **situation-specific operationally available**:

- **Timely** before it loses its capacity to play its role, and
- **On-site** at the required location (at hand for tasks to be performed).

Situation-specific operational timely and on-site availability are the *fifth* and *sixth* universally necessary, primary, and prerequisite use requirements for examining other requirements for an available factor in form. An available factor should also be actionably credible; otherwise, discontinue examination.

Actionably credible, reliable, and believable

An available factor in form must be examined for its credibility, for its fidelity, and for how true it is or how distant it is from reality. Observations, measurements, and communications are vulnerable to their inherent quality problems. Besides, of random errors, they are subject to bias by ignorance, wishful expectations, and intentionality. The ***ultimate*** intrinsic (naturally belonging to it) ***purpose of informing***, whether acknowledged or not, is to extend one's control over one's reality, whether physical or social. Among **living entities,** ***bias*** occurs with (a) communications received due to **ignorance** and **wishful thinking** of the one informed, and (b) communications sent by design due to **ignorance** and **purpose** of the communicator.

Entities informed should know how distant the considered information is from **valid information,** which serves here, as the main point of reference for the following distinctions:

- ***Disinformation*** is designed by the communicator to deceive. (For deception, *perfect disinformation,* the exact reverse of valid information cannot be used. Effective disinformation must contain valid elements to suggest credibility or reliability.) ***Misinformation*** misrepresents reality, on the one hand, due to malfunctioning of receptors (e.g., *instruments, eyesight, hearing,* etc), ignorance (e.g., *misinterpreted terminology, definition, language*), and unwarranted wishful expectations by the one informed, and, on the other hand, unintentionally by ignorance or on purpose by veiled design biased (custom-tailored, articulated) by the communicator to serve the current purpose of the communication sent.

- ***Valid information*** (the rarest of all) maps faithfully with high fidelity, the best being one to one, as defined by Wand and Wang (1996), or at least, with sufficient accuracy and precision, a fragment of reality into its representation.

This applies to competitive environments. Within willing alliances, organizations formed for higher competitiveness, the bias attributed to purpose is usually limited but not eliminated. Even organized crime enforces the rule, *"Never lie to your boss."* The exceptional nature of valid information necessitates creation of institutions and services that are based on trust by serving credible information. Misinformation and disinformation require careful design of counter measures (e.g., *double checking*) and contingency provisions (*never fully trust a single source*), including intelligence and counter intelligence.

From the perspective of the informing entity—communicator—effective communication is of main concern, how the actual results differ from the intended ones. Here, one deals with an even wider than above spectrum of miscommunications:

- ***Perfect communication*** – 100% effective (e.g., *all marketing targets ordered from us*), which serves here as the main point of reference;

A wide range of ***effective communications*** within the range of effectiveness between less then 100% and more than 0% (some of the marketing targets ordered from us);

- ***Miscommunication*** within the range of effectiveness between 0% and more than a negative 100% (e. g., *no one ordered from us but most targets ordered from our competition*);
- ***Discommunication*** – an abstract limit, where the result is the exact reverse of what was intended—a perfect failure (e.g., *no one ordered from our company, but all targests ordered from our competition*).

Here, the credibility of an examined factor will be further discussed only from the perspective of the one informed. Credibility is a complex function of at least 20 indirect factors (see more in Gackowski, 2006). Credibility of obtained information hinges on (1) traceability to their sources necessary to assess their respective reputations, and (2) faithful mapping of the real-world states into states of the delivery system and, later, into the data/information efficiently presented to users. The ***reputation of data or information sources*** is again a function of many other indirect properties, such as the definition of a factor adequate to the purpose, objectivity (unbiased), accuracy (error free), precision, and currency (up to date). Deficiency in any of them decreases the factor's credibility.

Credibility can be increased when the same information can be acquired from a variety of independent or even competing sources or can be confirmed by other assessment methods. Credibility may also be assured when the specialized process of massive data/information acquisition, entry, verification, validation, storage, availability, and, later, conversion into an interpretable format for presentation is subject to stringent use requirements, tests, and audit procedures. The more important, valuable, dangerous, litigation prone, and/or vulnerable to criminal activities a transaction item is, the less likely that a responsible manager would neglect traceability and transparency of its handling, including prevention of illegal or irrational acts (e.g., *unauthorized trading, unauthorized access to or moving of nuclear warheads*). Bad habits, however, trickle down from the top. Voting for an unread bill is clearly a dereliction of duty, leading to loss of credibility of the process, institution, and its leadership.

Full credibility is rarely-to-never attainable; frequently, users must act with only an acceptable level of credibility, denoted situation-specific ***actionable credibility.*** It can be defined as the degree of credibility at which users are willing to take action, which implies that they have enough faith to rely on a factor in form in action. It may be of perfect accuracy, precision, and currency; however, when, within the context of the conducted operations, decision makers do not sufficiently trust their veracity, it may be ignored. Many historical examples confirm it. According to historical sources, Hitler waited 3 days before he decided to launch a counter offensive against the Allies in Normandy with many still available SS tank divisions. Other sources say that he was effectively, however in a cruel manner, disinformed about the planned landing site. It confirms Schopenhauer's insight that humans act on the representations available to them, not on the actual reality. The definition of actionable credibility is precise, but its level is highly variable. It is a function of the decision situation, the circumstances of operations, and the personality of the decision maker, i.e., whether he/she is risk averse or trigger happy.

Gill (2008) a fruitful concept that applies to actionable credibility. A factor in form to become actionable must resonate with the mental model of a client; however it equally applies to all kinds of physical resonance whether mechanical, electromagnetic, or molecular, which confirms its universality in any kind of informing.

Situation-specific **actionable credibility** is the *seventh* universally necessary, primary, and prerequisite use requirement for examining other requirements for the factor. If actionable credibility cannot be attained, it always directly qualitatively and quantitatively affects operations. An actionably credible factor should meet also other necessary use requirements; otherwise, discontinue its examination for operations.

Other situation-specific necessary use requirements

An actionably credible factor may be subject to ***other situation-specific necessary primary use requirements*** such as restricted or exclusive availability so important in competitive situations, subject to a license, permission, security regulations, mandatory registration, prohibited by local laws, etc. This is the *eights,* this time a group of necessary, primary, and prerequisite use requirements for a factor in form to become usable; hence, it closes the list of primary use requirements for usability of a single factor in form.

Usability of a Factor: Sufficient Use Requirements

Situation-specific use requirements complete the list of ***universal and other necessary primary use requirements*** for situation-specific ***operational usability***; otherwise, it is ***operationally useless*** (see Appendix, Definition 14).

Uncertainty about factors' usability degrades decision situations. If usability of a factor in form is:

- **certain**, the situation is ***deterministic;***
- only **probable** (the most likely case), the situation is ***stochastic*** ;
- **nil, zero** (e.g., *not timely available*), the situation with regard to such factor is a ***game***.

Usable factors can be used, they are "fit for use," and, by default, they are ***effectively usable***, otherwise ***useless***. When ethics and/or economy matter, additional necessary secondary use requirements come into play.

Secondary Necessary Requirements: Ethics/Efficiency

Those who manage operations, the society within which they are conducted and other stakeholders may have higher expectations than merely effectiveness. Formally, if an **effectively usable factor** also meets the necessary ethical and/or economical requirements, then it becomes an ***ethically usable*** and/or ***efficiently usable*** factor, labelled respectively. They provide a sufficient reason that the factor is not only effectively, but also efficiently and/or ethically usable. Effective usability is a fundamental use requirement in operations. When operations are ineffective, neither ethics nor efficiency of informing matter.

A situation-specifically ***effectively usable factor*** may be directly or indirectly usable. If the directly or indirectly effectively usable factor meets also situation-specific:

- **ethical** use requirements, it is an ***ethically effectively directly*** or ***indirectly usable factor***;
- **efficiency** use requirements, it is an ***efficiently directly*** or ***indirectly usable factor***;
- both **ethical** and **efficiency** use requirements, it is both an ***ethically and efficiently directly*** or ***indirectly usable factor*** (see Appendix, Definitions 15c-f).

In routine operations, the use requirements for data stored in common databases should be max–min. If the concerned factor in form is a datum, the minimal levels of its use requirements for the most demanding task should be used in common databases. When properties of usable factors in form significantly exceed the max–min level of properties, any additional efforts to attain the required level are wasted resources (see Appendix, Definition 16).

When users of factors in form are different from those who prepare them, the former may face difficulties in recognizing, interpreting, understanding, and using them. Those users may be of different mindsets, cultural backgrounds, and conventions; speak different languages; etc. than those who gathered data. Thus, new aspects and problems of recognizeability and interpretability of factors emerge. Here again, we must distinguish between two levels: recognizable and economically recognizable and interpreted by indirect users as an additional situation-specific necessary primary use requirement, although not a universal one. All of the above may also become necessary, but they belong to the secondary use requirements for **efficient** operations.

Effectively, ethically, and/or efficiently usable factors to become actually useful must first become actionable and then become engaged in operations, but to this end, first they must be operationally complete for each task.

Operationally effectively, ethically, or efficiently complete

In operations, usable factors in form must be actionable so that one may act upon them. To this end, they must be operationally complete with regard to the tasks to be performed. For factors to become directly or at least indirectly useful, they also must be engaged in operations. Operational completeness is more complex than completeness of mapping reality or completeness of rows and columns in database tables, as it is usually interpreted. One must distinguish between two distinct levels: (1) operational completeness of usable factors for routine operations managed at the tactical level, and (2) the never-attainable cognitive completeness at the strategic management of operations. Operational completeness should be at least effective, but if effectively usable factors meet also ethical and economical primary requirements, one may attain ethical and/or efficient completeness.

Operations (whether repetitive or one-time) may be decomposed into a network of tasks. There is at least one important degree of task-specific completeness: when it becomes sufficiently effective to trigger a state transition in operations (to act or not). This, again, is a matter of doctrine and policy.

Effective completeness pertains to operations conducted with an *all-out effort,* such as military special operations or acts of terror according to their purpose when efficiency (e.g., *cost* or *lost lives of those who act*) is of secondary or of no concern. Only ethically and/or efficiently usable factors should be respectively tested for ***ethical*** and/or ***efficient operational completeness***.

Operational completeness measures the degree to which the usable data/information items are effectively operationally available. It may be expressed in percentage points (1 - 100%) as the ratio of the sum of the results that can be attributed to the corresponding items available and the sum of all the results possible with full completeness. In real-life situations, usually some residual operational results remain unaccountable. This means it is not possible to attribute them to the previously identified factors. They may be used as a relative or absolute measure of how incomplete the impact analysis of the situation was. The more of the task-specific factors are effectively usable, the more tasks may be effectively performed. Figure 1 illustrates the general

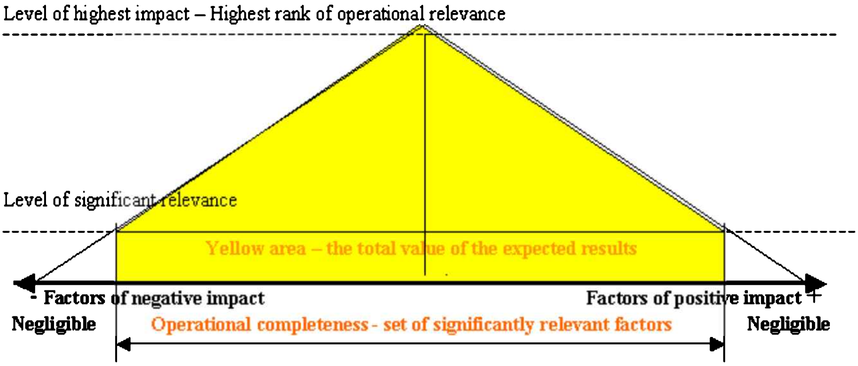


Figure 1 The relationship between significant relevance and operational completeness of data or information items pertaining to the corresponding factors that determine and contribute to the total value of the expected results in a decision situation under consideration.

interdependence between **impact** and **operational completeness** of data/information items.

Effective completeness pertains only to direct tasks, or at least its prerequisite tasks, that may trigger the execution of the direct task. Execution of a direct task should generate effects equal to its materiality. In order for a task to be a ***direct task*,** the task-specific cluster of usable factors must contain some factor(s) **adding value** to results (see Appendix, Definition 17). Operations (whether repetitive or one-time) may be decomposed into a network of tasks. There is at least one important degree of task-specific completeness: when it becomes sufficiently effective to trigger a state transition in operations (to act, cease, or modify action). This, again, is a matter of doctrine and policy. Of course, a direct task is effectively operationally complete if all effectively usable factors are available to be engaged (see Appendix, Definition 18).

Murkier is the qualitative or **cognitive** aspect of **completeness** of usable data/information. In real-life situations, in a fight for survival, on a battlefield, or in global business competition, one may never be certain whether all relevant success factors or dangers have been identified and evaluated. Prudence requires gathering pertinent information as much as possible so that decision makers may assess all the maybe not-yet-perceivable but potentially possible critical factors for planning of counter measures and contingency provisions. The critical blow most frequently comes from a danger or direction not identified and recognized in time. Cognitive completeness cannot be considered mandatory, because it is rarely to never fully attainable. Figure 2 illustrates the general interdependence between **impact** of data/information about all the identified hypothetical factors pertaining to a situation and the fuzzy notion of their ***cognitive completeness*** for strategic management.

Only task-specific complete usable factors are actionable and can be engaged in operations to become actually useful.

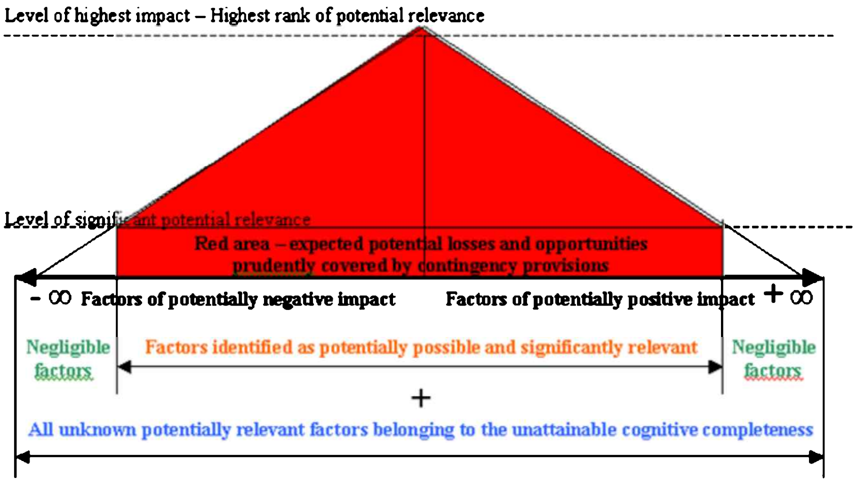


Figure 2 Relevance of data/information items about identifiable potential factors portaining to a decision situation under consideration and the unattainable notion of their cognitive completeness.

Usefulness of Factors—Sufficient Use Requirement

A usable factor may be ***directly useful*** only when it is task-specifically complete and is actually engaged in conducting an at least minimally operationally effective task; otherwise, it is wasted in ineffective operations or is a usable ***factor in waiting***, which is only ***indirectly useful***. Depending on whether a factor is effectively, efficiently, and/or ethically usable, it may become respectively ***effectively, ethically,*** and/or ***efficiently directly useful*** or only ***effectively, ethically,*** and/or ***efficiently indirectly useful***. They all are situation specific. Usefulness is not a distinguishing attribute of anything. Usefulness is always contextual, never intrinsic to factors, and applies to only some situations (see Appendix, Definition 19).

Sufficient Reason to Trigger, Conduct, Change, or Cease Operations

We have reached the point to ask the last question: What provides the chief executive decision maker with a sufficient reason to trigger operations? The answer to this question is simple and complex at the same time. The key to the answer provides the Schopenhauer's worldview in his opus vitae, *The World as Will and Representation* (Hamlyn, 1980) and his doctoral dissertation, *The Fourfold Root of Sufficient Reason* (Schopenhauer, 1974).

The simple answer is that the will of the chief executive decision maker is always a sufficient reason to trigger, conduct, change, or cease operations, based simply on his/her emotions, as it frequently happens. However, our will may be controlled by intellect. The decision may be an outcome of planning, preparations, and calculations; however, all of them are based on the available representation of the situation provided by others of influence. As always, assessment is emotionally loaded with wishful expectations and projections. If not guided by emotions, the operations under consideration must be perceived sufficiently or insufficiently effective, ethical, and/or efficient to be triggered, conducted, changed, or ceased.

Ultimately, what is sufficiently effective, ethical, and/or efficient is always subjective and mixed with emotions of the beholder—the chief executive decision maker (CEDM). This the way humans act in personal matters, the way they launch new and fold old businesses, and the way they wage small and worldwide wars and/or declare un unconditional surrender. Usually, programmed and numerically controlled devices are devoid of emotional factors. However, we witness research and development successfully adding emotional aspects of behaviour to robots; they can take into account emotional states of others and learn to react accordingly.

To realize how differently the examination of the use requirements of factors in form can be conducted, it may help to compare the examination of completely unknown factors with the one practiced with routine information for routine operations.

Simplified Assurance of Use Requirements

In ***routine*** operations, the impact of factors is viewed and perceived differently by decision makers and/or users than it is in a case of factors acquired or received for the first time for strategic purposes. In routine operations, the role of individual factors in form is relatively well known. Those deemed useful are stored in common databases and warehouses to be shared among many users; one may say that they have been internalized. Thus, in routine operations:

1. factors can be easily **recognized.**
2. factors are of established **operational relevance** and **meaning.**
3. **materiality** of factors is experienced differently for different applications.
4. **availability** of factors stored for common use is assured for all users but limited by rules of authorized access. Exactly the opposite occurs with the strategic factors frequently extracted with great difficulty from the outside world and reluctantly shared with others.
5. **Credibility, reliability, and believability** of factors is less the concern of individual internal users but is or should be subject to established rigorous procedures of assurance on behalf of all users—verification, validation, monitoring, and auditing.
6. **completeness** of usable data, in most cases, boils down to a careful design of a corresponding *subschema* for application processing and predefined inquiries. This starkly contrasts with problems in strategic management—*"connecting the dots from disparate sources."*

Whenever requirements are discussed, invariably a fundamental question is asked: how they can be objectively classed and ordered?

Table 3 A simplified summary of the universal taxonomy and ordering of quality requirements related to the use of factors in form, types of factors' usability, and degrees of their involvement in operations

The universe of quality requirements related to use of factors in form that affect operations and results

Factors that directly and indirectly affect decision situations, implementation, and/or results of operations

Factors in form qualified to play a role in operations	Usable	Primary necessary quality requirements	Operationally recognized and			or not	Operationally disqualified – useless factors
			Operationally relevant and			or irrelevant	
			Operationally meaningful and			or meaningless	
			Operationally significantly material and			or insignificant	
			Operationally timely available and			or timely unavailable	
			Operationally on-site available and			or on-site unavailable	
			Actionably credible or reliable and			or unreliable for action	
			Meet situation-specific requirements			or do not meet them	
	Engaged to some degree in operations		*Factors effectively usable* – meet the primary quality requirements and are partially ordered by materiality			*As such operationally disqualified and useless for routine operations*	
			Affect results directly		Indirectly		
			Complete & engaged - directly useful	In waiting - indirectly useful	Ordered by materiality & distance from the affected direct factor		
		Secondary NQRs	*Factors ethicaly and/or efficiently usable* – meet the primary secondary necessary requirements and ordered by degree of efficiency				
			Affect results directly		Indirectly		
			Complete & engaged - directly useful	In waiting - indirectly useful	Ordered by degree of efficiency & distance from the direct factor		

Taxonomy and Ordering of Quality Requirements Related to Use of Operation Factors

When viewed from the teleological perspective of operations through the lens of decision making, the entire universe of quality requirements related to the use of factors in form is subject to a universal disjoint taxonomy and ordering.

All of the above is more formally presented in the Appendix. A simplified summary of the universal hierarchical impact-focused taxonomy of quality requirements related to the use of factors in form for operations is shown in Table 3.

Priorities in Research and Examination of Use Requirements of Factors

Once a point of reference and a result-determined taxonomy of the use requirements of factors in form have been defined, one can prioritize their examination for research and practical applications.

1. Examine the necessary primary use requirements, which make factors in form usable and directly affect the decision situation, the implementation of decisions, and the results of operations. Some are always necessary, hence universal. The non-universal other necessary requirements are also situation specific. Both are at least nearly well ordered by combining two criteria: their strength as prerequisites and the difficulty of their examination. Changes to necessary requirements always qualitatively and quantitatively change results. This examination determines whether effective use of information is feasible at all.
2. If any of the primary use requirements are of potential high materiality and can not been met, examine them by decreasing materiality with regard to the indirect factors that affect them. Maybe by improving on them the direct primary one could be met. The necessary use requirements of the indirect factors inherit the materiality of the direct factor. The indirect use requirements can also be well ordered by combining three criteria: materiality, difficulty of their examination, and the distance from which they affect the direct one (of the first, second, and subsequent orders).

3. If operations ought to meet higher expectations, examine the secondary necessary use requirements that make operations ethical and/or at least minimally efficient with regard to their implementation, and results. They are at least nearly well ordered by combining three criteria: materiality, strength as prerequisites, and difficulty of their examination.

Finally, examine the gradable use requirements to determine whether further improvements are feasible. Changes to desirable gradable use requirements cause mainly quantitative changes unless they reach a critical point (e.g., *melting, freezing*) and then cause qualitative changes. They are at least nearly well ordered by, again, combining two criteria: their impact on efficiency and the difficulty of their examination.

The presented framework and model are anchored in basic scientific principles. As such, before embarking on extensive empirical validation, the model should be scrutinized by attempting to come up within its limitations with examples to the contrary or other objections with regard to the logic of the model, which then will need revisions.

The Informing Science Framework: Refinements

In 1999, Eli Cohen defined the Informing Science Framework. As a byproduct of this inquiry into informing systems for operations, some refinements may be identified. Cohen refers to Shannon's model, with information as a factor that reduces uncertainty or entropy experienced by the receiver. Shannon defined mathematically the **amount** or **quantity of information**, not information per se. It is not a conceptual (or a "real," by Leibniz) definition of **information** in this sense. *"We should not confuse a measure of a thing with the thing measured, let alone to confuse the metric with the thing measured by,"* as N. Callaos and B. Callaos (2002) remarked. The reduction of entropy pertains to a *closed system,* as is the case with technical communications systems. Based on this premise, Cohen says, *"... information is defined in terms of the receiver's level of uncertainty. In the field of Information Systems, we would say information is defined as that which reduces risk for the decision-maker."* This, however, only may be so.

Operations are *open systems;* work systems exchange inputs and outputs with their environments. Here, incoming information may actually increase the level of uncertainty or risk (e.g., *new threats*). The entropy of such decision situations increases. It can be computed in a well-defined situation. This may not occur in a closed system. Once both the one who informs and the one informed know the same, they are in the same state, and the entropy of such closed communication system is decreased, but decision making is not part of the communication model. Thus, within the confines of decision situations, one may say that, when an entity informed received a message about something (1) new, unknown, uncertain, and/or (2) changed the state (value) of any known variable of the situation under consideration, the message conveys a non-zero amount of information; it informs; it is ***information***. Such information, if usable and useful, always changes the **operation results** and/or the **decision situation** itself and/or the **implementation** of the decisions made, but, in some cases, it may also increase risk for decision makers. Any uncertainty about usability of information degrades decision situation models.

Part of the informing process is performed by **information delivery systems**. The description of delivery systems needs some extension. It is true that *"Information technologies are not limited to computing; they entail also other media that augment communication such as video, voice, and personal contacts."* However, *"any contacts, whether personal or impersonal,"* should be part of the framework. An arrangement of physical objects (*stocked merchandise, clogged freeway ahead*) informs effectively and even efficiently (Gackowski, 1982). These are examples of how entities informed (e.g., *drivers, shopkeepers)* actively deal with the changing reality by gathering information about the situation by assessing some of the moving informing entities (e.g., *cars, stocked merchandise*); these are **impersonal** contacts. Small inventory-control applications for street-corner shops commonly used this approach in the pre-computing era. Such informing is purely "impersonal." It is the simplest and least expensive informing although not favored by IT professionals and the IT industry they serve.

Thus, Cohen's (1999) word definition of the Informing Science Framework shown in Chapter 2 might be extended as follows:

"In the field of Information Systems that support operations, information is a factor in form that symbolically represents reality (objects, events, and their states) that changes the results and/or changes the decision situation by itself and/or the implementation of the decisions made. First, information must be usable by meeting the primary necessary use requirements. It may become useful only when engaged in operationally effective complete task-specific sets. When ethics and/or efficiency matter, the usable information must also meet the secondary necessary requirements." (The suggested extension prevents informing from degenerating into information pollution.)

"Information technologies are not limited to computing. Communication includes video, voice, and any contacts, whether personal or **impersonal.**"

Conclusions

One may conclude this inquiry with the following observations:

Examination of informing processes requires a clear distinction between **active** and **passive informing** because their examination, design, operations, and impact differ considerably.

In ***active informing,*** the source is active if by design it becomes the communicator or disseminator of information and tries to affect the behavior of the targeted entity informed.

In ***passive informing,*** the source is passive; the entity informed is provided with or tries to gather intelligence about its envirnoment when a significant difference in results is expected.

- Clients—entities informed—are acting agents always relatively autonomous in their actions, whether individuals, their organizations, or devices (if devices, usually controlled numerically by programs and/or artificial intellignece) to be able to act differently, if informed.
- Clients can be active or passive with regard to the information flow, for they may actively search for the desired information or may more or less attentively wait for it; hence, the information flow may be a solicited or unsolicited one.
- Measurable or perceivable results or benefits are expected; in **active informing by design,** mainly by the communicator, and in **passive informing,** mainly by the one informed—usually by both.

This inquiry identified several universal conditions for informing, use requirements for factors in form with their materiality as a fundamental, central, and the most pervasive use requirement in operations; and the sufficient requirements for usability and usefulness of factors in form.

It demonstrated the universality of the result-focused taxonomy of well-ordered (at least nearly use requirements for factors in form, their quality aspects and properties, tasks, and decision variables. Their ordering prioritizes their examination for research and practical applications. In operations, the teleological (purpose-focused) framework of informing seems to serve best. As a byproduct of this inquiry, two suggestions with a supporting rationale are presented on how the Cohen's (1999) Informing Science Framework shown in Chapter 2 might be refined. To the best knowledge of the author, no one else conducted similar inquiries.

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Appendix – Formal Definitions and Formulas

Use Related Quality of Operation Factors

Definition 1: Generally, ***quality Q*** is an infinite **multidimensional space of quality dimensions, aspects,** or attributes of distinctive characteristics called **quality aspects q,** formally,

$\boldsymbol{Q} = \mathbf{q_1 \times q_2 \times \dots q_i, \dots \times q_\infty}$, where i belongs to a set of ordinal numbers i 0{1, 2 ... ∞}

Definition 2: ***Distinguishing quality - $Q_D(F)$ of a class F of factors f*** 0 ***F*** (e.g., *aerial pictures, vectors, text messages*) is a finite multidimensional space of the **necessary** (e.g., *resolution, precision, length*) **quality aspects $nq_i(F)$** of cardinality k = ||(nq(F))|. Necessary distinguishing quality aspects of factors facilitate compression of knowledge. Formally,

$$Q_D(F) = nq_1(F) \times nq_2(F) \times \dots nq_i(F) \dots \times nq_k(F)$$

Definition 3: ***Quality of a specific factor*** (e.g., *tool, data value*) ***f - Q(f)*** is defined by a vector of states—properties (e.g. ,*true, false*)—of **necessary** (e.g., *credibility*) **nq(f) 0 NQ(f),** and **other** (e.g., *acquisition cost*) quality aspects **oq(f) 0 OQ(f).** Of course, Q(f) = NQ(f) ∪ OQ(f). Formally,

$\boldsymbol{Q(f)} = \mathbf{[s(q_1(f)), s(q_2(f)), \dots s(q_j(f)), \dots s(q_n(f))]}$ for each q(f) 0 Q(f) of cardinality n = ||Q(f)||.

Any quality aspect q(f) of factor f can take on one out of two or more distinguishable states—properties $s_j(q(f))$ 0 S(q(f))—of their quality aspects q(f) 0 Q(f) of factor f 0 F, where j 0 {1, 2 … n} and cardinality n = ||S(q(f))|| > 1. A ***set of states—properties s(q(f)) of a quality aspect q(f)***—can be Boolean {true, false}, defined by enumeration or an ordered set of numbers. The last implies ranking of properties (e.g., *materiality, size, caliber of fire arms, etc.*).

Definition 4: ***Quality requirements QR(f)*** (e.g., a certain degree of *precision, accuracy, currency*, etc.) for a specific factor f are defined by a vector of **required properties—states of quality aspects - rs(q(f)) 0 RS(q(f))**. Formally,

$\boldsymbol{QR(f)}$ = **[rs(q_1(f)), rs(q_2(f)), … rs(q_n(f))]** for each q(f) 0 Q(f) and n = | | Q(f) | |.

<u>**Assumption 1**</u>: ***M(f)—Materiality of a specific factor f—*** *is* a function Φ of the materiality **M** of all its **properties** s(q(f)) 0 S(q(f) for of each quality aspect q(f) 0 Q(f) of the factor f, formally, ***M(f)*** = **Φ[M(S(q(f))**)] for properties s of quality aspects q(f) 0 Q(f) of the factor f.

<u>**Assumption 2**</u>: ***Materiality M(S(q(f))) of most properties*** **s 0 S** ***of most quality aspects q*** **0 Q** ***of factor f*** **0 F** is subject to the law of **diminishing returns** (2008); hence, each quality aspect should be used at its **optimum** $\mathbf{s_{opt}}$ or **acceptable** $\mathbf{s_{acc}}$ state. It implies, for most quality aspects **q** their subsequent improvements (changes) of their properties **s** do not monotonically improve efficiency of operations.

<u>**Definition 5**</u>: ***Significant operational quality*** $\boldsymbol{Q_S(f)}$ of a factor **f 0 F** is defined by its **significant properties** (states of quality aspect) **sp(q(f)) 0 SP(Q_S(f))** of its significant quality aspects **q(f) 0 Q_S(f)**, which qualify the factor to play a significant role in operations. It is a vector of significant properties in the quality space of the factor **Q_S(f)**. Formally,

$\boldsymbol{Q_S(f)}$ = **[sp(q_1(f)), sp(q_2(f)), … sp(q_i(f)), sp(q_n(f))]** for each q(f) 0 Q_S(f) of cardinality n = | | Q_S(f) | |

<u>**Definition 6**</u>: The ***state s*** (not measure) ***of quality Q of operations O - s(Q_O)*** is defined by a set $\mathbf{S_{QV}}$ of vectors **qv 0 S_{QV}** of significant properties with regard to all significant quality aspects **q(f) 0 Q(f)** of all significant factors **f 0 F** with regard to the purpose **P** with the threshold of significance **S_{min}(ΔM_{RO})** effective under significant states of nature **SN**. It is an ordered septet ***s(Q_O)*: = < M_{RO}, P, S_{min}(ΔM_{RO}), F, Q(F), S_{QV}, SN >** where

- **M_{RO} = M_{RO}[P, s(q(f)), SN]** over each s(q(f)) 0 S(Q(f)), q(f) 0 Q(f), and f 0 F is a measure of the results of operations
- **P** – the purpose of operations
- **S_{min}(ΔM_{RO})** – the threshold of significance expressed as the smallest increment of Δ$\mathbf{M_{RO}}$
- **F** – set of significant factors **f**
- **Q(F)** – sets of significant quality aspects **q(f) 0 Q(f)** for all f 0 F
- $\mathbf{S_{QV}}$ – set of vectors **[sp(q(f))]** of significant properties s(q(f)) 0 S(q(f)) of significant quality aspects q(f) 0 Q(f) of significant factors f 0 F

- **SN** – a set of significant states of nature (beyond the decision-maker's control)

<u>Definition 7:</u> ***Significant materiality of an entity e*** (here, factor or its property) is the difference in the measure of the results of operations $\mathbf{M_{RO}}$ when acting with and without the entity e and the difference is not less than the threshold of significance $\mathbf{S_{min}(\Delta M_{RO})}$, formally, ***M(e)*** = **M(E) – M(E-e)**, where e 0 E.

<u>Definition 8</u>: In operations, each (**Λ**) significant state **s** of significant quality **q** of significant factor **f** in a situation defined by a vector of significant states of nature **SN** with regard to purpose **P** by a selected criterion $\mathbf{M_{RO}}$ are ***the optimal or acceptable state*** $\boldsymbol{s_{opt/acc}}$ when the results are optimal or acceptable **(OPT/ΛCC),** formally,

$\mathbf{\Lambda[s(q(f))} = \mathbf{s_{opt/acc}(q(f))}$ when $\mathbf{M_{RO}(s(q(f))) = OPT/\Lambda CC(M_{RO})]}$ for all s 0 S(q(f)), q(f) 0 Q(f), and f 0 F. A vector of such states defines by enumeration the optimal or acceptable state of quality of operations.

<u>Definition 9</u>: ***The optimal or acceptable state*** $\boldsymbol{s_{op/acct}}$ (not measure) ***of quality*** $\boldsymbol{Q_O}$ ***of operations O*** that is $\boldsymbol{s_{op/acct}(Q_O)}$ is defined by a set $\mathbf{S_{opt/accQV}}$ of quality vectors $\mathbf{[s_{opt/acc}(q(f))]}$ of optimal or acceptable states $\mathbf{s_{opt/acc}(q(f))}$ with regard to all significant quality aspects **q(f) 0 Q(f)** of all significant factors **f 0 F** with regard to the purpose **P** with the threshold of significance $\mathbf{S_{min}(\Delta M_{RO})}$ in a situation described by significant states of nature **SN** if the measure of operation results is optimal of at least acceptable $\mathbf{OPT/\Lambda CC(M_{RO})}$. It is an ordered septet $\boldsymbol{s_{opt/acc}(Q_O)}$: = < $\mathbf{OPT/\Lambda CC(M_{RO}), P, S_{min}(\Delta M_{RO}), F, Q(F), S_{opt/accQV}, SN}$ > where

- $\mathbf{OPT/\Lambda CC(M_{RO})}$, where $\mathbf{M_{RO}[P, S(Q(F)), SN]}$ for all s(q(f)) 0 S(Q(f)), q(f) 0 Q(f), and f 0 F is a measure of the results of operations
- **P** – the purpose of operations
- $\mathbf{S_{min}(\Delta M_{RO})}$ – the threshold of significance expressed as the minimal increment of $\mathbf{\Delta M_{RO}}$
- **F** – set of significant factors **f**
- **Q(F)** – sets of significant quality aspects q(f) 0 Q(f) for all f 0 F
- $\mathbf{S_{opt/accQV}}$ – set of quality vectors $\mathbf{[s_{opt/acc}(q(f))]}$ of optimal or acceptable states $s_{opt/acc}(q(f))$ for all q(f) 0 Q(f) and f 0 F
- **SN** – a set of significant states of nature (beyond the decision-maker's control)

Primary Necessary Use Requirements

Operationally recognized

A vector **rv** of values that represents a factor in form to be recognized must match some (qualifier V) familiar types of entities, variables, objects, events, quality aspects, properties, states of mind, situations, or states of a robotic device **sm 0 SM** of the entity informed.

<u>Definition 10</u>: **IF V(rv = sm)** for sm 0 SM **THEN** the vector ***rv*** is ***situation-specifically operationally recognized as representing an entity*** $\mathbf{e_x}$ subject to further examination.

Operationally relevant

Formally, if the recognized entity $\mathbf{e_x}$ matches some (V) elements **f** of the actual significant operational factors f 0 F(T), it is operationally relevant. The latter is the union $\bigcup$ of clusters of factors **cf(t)** necessary for all elementary tasks t 0 T (closed set of all tasks) in the network, into which operations O can be decomposed as practiced with PERT (Moder et al., 1983): $F_O(T) = cf(t_1) \bigcup cf(t_2) \ldots \bigcup cf(t_n) = \bigcup cf(t)$ for all t 0 T, and n = cardinality of | |T| |.

<u>Definition 11a</u>: **IF V($\mathbf{e_x}$ = f)** for some f 0 $F_O(T)$ **THEN** the **recognized** entity $\mathbf{e_x}$ is situation-specifically ***operationally relevant*** and becomes a **recognized** and **relevant** operational **factor** $\mathbf{f_x}$ subject to further examination.

With a formal model of operations, one may define operational relevance in relation to its operational variables **ov**.

<u>Definition 11b</u>: **IF V($\mathbf{e_x}$ = ov)** for some ov 0 OV **THEN** the recognized entity $\mathbf{e_x}$ is situation-specifically ***operationally relevant*** and becomes a **recognized** and **relevant** operational **variable** $\mathbf{ov_x}$ subject to further examination.

Of operational meaning

If the examined relevant factor $\mathbf{f_x}$ makes a non-zero difference or a not (5) empty **Θ** set of differences $\mathbf{O_M(f_x)}$ between the current and previous outcomes denoted $\mathbf{O_c(f_x)}$ and $\mathbf{O_p}$ of the operations model $\mathbf{O_M}$ then it is a factor $\mathbf{f_m}$ of situation-specific ***operational meaning***.

<u>Definition 12</u>: **IF $\mathbf{O_M(f_x) = [O_c(f_x) - O_p] \neq 0}$ or not Θ THEN** the examined factor $\mathbf{f_x = f_m}$ is of ***situation-specific operational meaning***; it becomes an operationally **recognized, relevant,** and **meaningful factor**.

Significantly material

If materiality $\mathbf{M(f_m)}$ of the examined (here: recognized, relevant, and meaningful) factor $\mathbf{f_m}$ exceed the established minimal threshold $\mathbf{S_{min}(\Delta M_{RO})}$, then it is of situation-specific ***operationally significant materiality***.

<u>Definition 13</u>: **IF** $[\mathbf{M(f_m)} \geq \mathbf{S_{min}(\Delta M_{RO})}]$ **THEN** $\mathbf{f_m = f_{sm}}$ is of situation-specific ***operationally significant materiality*** and becomes an operationally **recognized, relevant, meaningful,** and **significantly material factor**.

Each **(ϖ)** factor directly adding value avf 0 AVF confers its materiality on its corresponding necessary companion factors ncf 0 NCF, formally, ϖ **[M(ncf(avf)) = M(avf)]** for each ncf 0 NCF, avf 0 AVF

Usability of Factors: A Sufficient Quality Requirement

If an examined factor **f** meets the entire above universally necessary primary and other necessary primary use requirements, it constitutes a <u>sufficient</u> reason for the factor to be considered a situation-specifically ***effectively usable factor euf***.

<u>Definition 14</u>: **IF** $\{\mathbf{f_x} \equiv$ operationally recognized($\mathbf{f_x}$) ^ operationally relevant($\mathbf{f_x}$) ^ of operational meaning($\mathbf{f_x}$) ^ operationally significantly material($\mathbf{f_x}$) ^ operationally timely available($\mathbf{f_x}$) ^ operationally on-site available($\mathbf{f_x}$) ^ actionably credible($\mathbf{f_x}$) ^ meets the other situation-specific necessary primary use requirements($\mathbf{f_x}$)$\}$ **THEN** $\mathbf{f_x}$ **=** ***euf*** that denotes a ***sufficiently operationally usable factor.***

Secondary Necessary Use Requirements: Ethics Efficiency

Formally, if an **effectively usable factor euf** meets also the necessary ethical and/or economical requirements, then it becomes an ***ethically usable*** and/or ***efficiently usable*** factor labelled respectively ***ethuf*** and ***effuf***.

<u>Definition 15a</u>: ***Ethically*** means it meets for instance the *Widely Endorsed Standards of Corporate Conduct* in Pain (2005).

<u>Definition 15b</u>: ***Economically*** means at joint cost $\mathbf{JC(f_x)}$ significantly less than its materiality $\mathbf{M(f_x)}$, hence $\mathbf{M(f_x) - JC(f_x) \geq S_{min}(\Delta M_{RO})}$

Sufficient Reasons for a Factor to Become Effectively, Ethically, and/or Usable

A ***situation-specifically effectively usable factor - euf*** may be directly (***deuf***) or indirectly usable (***ieuf***). Effective usability is a fundamental information use requirement (IQRs) in operations. If the directly or indirectly effectively usable factor (**euf**) meets also situation-specific

- **ethical** use requirements, it is an ***ethically effectively directly (dethuf)*** or ***indirectly usable factor (iethuf)***;
- **efficiency** use requirements, it is an ***efficiently directly (deffuf)*** or ***indirectly usable factor (ieffuf)***;
- both **ethical** and **efficiency** use requirements, it is both an ***ethically and efficiently directly (detheffuf)*** or ***indirectly usable factor (ietheffuf).***

<u>Definition 15c:</u> **euf** ≡ ***deuf*** v ***ieuf.***

<u>Definition 15d:</u> **(deuf ^ ieuf) ^ IQRs(ethics)** ≡ ***dethuf*** v ***iethuf.***

<u>Definition 15e:</u> **(deuf ^ ieuf) ^ IQRs(efficiency)** ≡ ***deffuf*** v ***ieffuf.***

<u>Definition 15f:</u> **(deuf ^ ieuf) ^ IQRs(ethics)** ^ **IQRs(efficiency)** ≡ ***detheffuf*** v ***ietheffuf*.**

If the concerned factor **f** is represented by a data value **d**, hence **f = d**, the minimal use requirements **qr** for quality aspects **q(d,t)** for the most demanding task **t 0 T** should be used for the data value **d** stored in a common database. Formally, then the maxi–min use requirements for common data are

<u>Definition 16:</u> ***max-min(qr(q(d,t)))*** **= max(min(qr(q(d,t)))** for q(d,t)) 0 Q(d,t)), t 0 T.

Operationally effectively, ethically or efficiently complete

For a task to be a ***direct task dt,*** its task-specific cluster CUF(t) of usable factors euf must contain some (V) factor(s) **adding value avf(t) 0 AVF(t)** to results:

<u>Definition 17</u>: **IF {(euf** 0 **CUF(t)) ^ V [(euf** 0 **AVF(t))]** for euf 0 CUF(t)} **THEN** the **task t =** ***dt*** is a ***direct task.***

A direct task **dt** is effectively operationally complete—**eoc(dt)**—if all effectively usable factors $\mathbf{euf_i}$ **= CUF(dt)** are available to be engaged for i = {1, 2, … n}, where cardinality **n = ||CUF(dt)||**, formally,

<u>Definition 18</u>: **IF {(CUF(dt) =** $\mathbf{\{euf_1, euf_2, \ldots euf_i, \ldots euf_n\}}$ for i = {1, 2, … n}, where **cardinality n = ||CUF(dt)|| THEN dt =** ***eoc(dt)*** (*effectively operationally complete* direct task).

Usefulness of Factors: Sufficient Quality Requirements

If an examined $\mathbf{f_x}$ is an effectively usable factor **euf** is engaged in some effectively operationally complete clusters **eoc** of usable factors in a direct task **dt** or any prerequisite task **tpt** that triggers the direct task **dt**, then $\mathbf{f_x}$ is a ***directly useful factor (duff)***; otherwise it is a ***usable factor in waiting (wf)***, which is only ***indirectly useful***:

<u>**Definition 19**</u>: **IF {V [$\mathbf{f_x}$ = euf 0 eoc(dt** or **tpt(dt))** for some eoc(t) 0CUF(T) for each task t 0 T)} **THEN $\mathbf{f_x}$ = *duff* ELSE $\mathbf{f_x}$ = *wf*.** It provides sufficient reason that the examined factor is also directly or only indirectly useful. It equally pertains to ethically and/or efficiently usable factors.

The same applies to ethically and/or efficiently usable factors in a corresponding way.

Taxonomy and Ordering of Quality Requirements

The ***universal hierarchical impact-focused taxonomy of quality requirements related to the use of factors in form*** (data, information, elements of knowledge) ***for operations***

1. subdivides their universe QR into **direct** and **indirect** ones and **orders** them partially (asymmetric, transitive) by **materiality** acquired from the use of the attributed factor.

   - changes from the previous state s_p to the current state s_c of a ***direct quality requirement of their use*** s(dqr), where dqr 0 DQR $\subset$ QR $\subset$ Q—the quality space—**immediately affect** the decision situation itself, the actions to implement the decisions made, and/or the results of operations, which implies they change the value of the adopted measure of results of informing ΔM_{RI}, formally, $(s_p(dqr) \neq s_c(dqr)) \Rightarrow (\Delta M_{RI} \neq 0)$.
   - Similar changes of states of an ***indirect quality requirement of their use*** s(iqr)), where iqr 0 IQR $\subset$ QR, as the name suggests, only **indirectly affect** the situation because it determines or contributes to properties of indirect aspects of qualities of a higher order (closer to the direct ones and at the upper end of the chain, to the direct aspects of quality). When s_p and s_c denote, respectively, the previous state and the current state of an indirect aspect of quality, and iq_n and iq_{n-1} denote, respectively, indirect aspects of quality of the n^{th} order and indirect aspect of quality of a higher $(n-1)^{th}$ order (for n = 1 indirect aspect of quality of 0^{th} order is a direct aspect of quality $iqr_0 = dqr$). It implies that a change of state of an indirect aspect of quality of the n^{th} order causes a change of state of the related indirect aspect of quality of the higher order

$i_{n\text{-}1}qr$ or, at the extreme, of a direct aspect of quality: $(s_p(iqr_n) \neq s_c(iqr_n) \Rightarrow (s_p(iqr_{n-1}) \neq s_c(iqr_{n-1}))$. Elements of this subclass are also partially ordered by their distance in the chain of functional dependencies from their respective direct aspects of quality they indirectly affect.

2. Similarly, the direct and indirect quality requirements related to the use of factors in form in operations are further subdivided into **necessary** and **desirable** ones. The necessary ones are usually **binary** and the desirable ones **gradable**. The gradable ones, however, may be both necessary with regard to the minimum and maximum of their range and between gradable with regard to the desirability of their intensity. Whichever use requirement is necessary, by default, it is a prerequisite quality requirement denoted **pqr**. A prerequisite quality requirement, if not met, precludes further examination of the entity. Individual factors in form that meet their necessary quality requirements are ***usable;*** otherwise, they are ***useless***. The usable ones, depending on the level of expectations, may be **effectively**, **ethically**, and/or **efficiently usable**. The efficiently usable can also be partially ordered by the level or degree of their efficiency.

   - Changes to the ***binary necessary quality requirements*** s(bqr(f)) of a factor f—their required states s or required properties (bqr(f) 0 BQR(f) $\subset$ QR(f) $\subset$ Q—the quality space) result in *qualitative and quantitative* changes of decision situations. They may add or eliminate a factor from consideration, where $\mathbf{F_c}$ and $\mathbf{F_p}$ are, respectively, the current and the previous sets of significant factors F. Formally: $\mathbf{[s_p(bqr(f)) \neq s_c(bqr(f))] \Rightarrow [(F_p \neq F_c) \wedge (\Delta M_{RI} \neq 0)]}$. This leads to a partial redefinition of the decision situation with qualitative and quantitative consequences.

   - Changes to ***gradable necessary quality requirements*** s(gqr(f)) of a factor f—their required states s or properties (gqr(f) 0 GQR(f) $\subset$ QR(f) $\subset$ Q—the quality space) mainly *quantitatively* change the results of operations; hence, they may not be significant ($\Delta M_{RI} \geq$ Min (ΔM_{RI})), unless the quantitative changes reach a critical state s_c 0 C(s(gqr)) (member of critical states C), they may also trigger qualitative changes. Formally:
     $\mathbf{[s_p(gqr(f)) \neq s_c(gqr(f))] \Rightarrow [(\Delta M_{RI} \neq 0) \wedge If\ (s_c(gqr)\ 0\ C(s(gqr))\ then\ (F_p \neq F_c)]}$.

   - Changes to the only ***desirable gradable quality requirements*** s(**dgqr(f)**) of a factor f—their required states s of properties (dgqr(f) 0 DGQR(f) $\subset$ QR(f) $\subset$ Q (the quality space)—only quantitatively change the results of operations; hence, they may not

be significant ($\Delta M_{RI} \geq$ Min (ΔM_{RI})). Formally:
$[s_p(dgqr(f)) \neq s_c(dgqr(f))] \Rightarrow [(\Delta M_{RI} \neq 0)$.

3. Similarly, the necessary (prerequisite) use requirements for factors in form in operations are divided into **primary** and **secondary necessary quality requirements**. ***Necessary*** requirements are of the highest importance and exactly of the same consequences; if not met, they make the factor unacceptable for operations. For economy, the necessary requirements should be examined by their descending ***strength as prerequisites*** measured by the number of the remaining necessary requirements that need not be tested, if the examined requirement is not met. It orders them ***partially (asymmetric, transitive)***, but when some of them are of equal strength as prerequisites, one may ask which of them is easier to test and order them partially by the increasing **difficulty of their examination**. Both criteria combined provide for ***well ordering*** of necessary quality requirements, for the **axiom of choice** (2008) in the set theory is satisfied.

   - The ***primary necessary*** ones are those determined by the nature of the situation, thus objectively independent of the decision maker.

   - The ***secondary necessary quality requirements*** can be controlled and manipulated, whether legally or not, by the chief executive decision maker; thus, they actually are **dependent requirements**. They usually pertain to **ethics** and **efficiency** of operations.

4. Subdivides the primary quality requirements into **universally** or **situation-specific necessary:**

   - The u***niversally necessary quality requirements*** of a factor **f** are always necessary. Changes to them s(unqr(f)), where unqr(f) **0** UNQR(f) $\subset$ QR(f) $\subset$ Q **(**the quality space) add or delete the affected factors from consideration: $[s_p(unqr(f)) \neq s_c(unqr(f))] \Rightarrow (F_p \neq F_c)$.

   - The ***situation-specific necessary quality requirements*** of a factor $f = f_{ssqr}$ are also necessary but not always. In specific situations, changes to them s(sspqrf), where ssnqr(f) **0** SSNQR(f) $\subset$ QR(f) $\subset$ Q **(**the quality space), also add or delete the affected factors in form from consideration: **If** $\{ f = f_{ssqr} \}$ **THEN** $[s_p(ssnq(f)) \neq s_c(ssnq(f))] \Rightarrow (F_p \neq F_c)$ (e.g., *restricted availability of a factor in a competitive situation*).

5. Subdivides the usable factors in form (subclass 1a) into **actionable** or **not.** To become actionable, the factor must be tested for completeness with regard to the tasks at hand to be performed (see Definition

SQRD4**)**. Only those actually engaged in the conducted operation are directly useful. Whether the factors are **effectively, ethically,** and/or **efficiently usable,**

- the engaged ones may be ***directly effectively, efficiently, and/or ethcially useful***;
- otherwise, they are ***indirectly effectively, efficiently, and/or ethically useful factors in waiting***—when need for them arises.

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Chapter 5

Expanding the Concept of Usability

Alex Koohang

Introduction

The *Informing Science* discipline is "…a number of disparate fields that share some common goals." The term *Informing Science* "… applies to disparate fields that share the common goal of providing a client with information in a form, format, and schedule that maximizes its effectiveness. The definition points to three interrelated components: the client, the delivery system, and the informing environment… The purpose of the informing environment is to provide information to the client. The delivery system refers to the use of information technologies that support the implementation of informing environments. The driving force behind the creation of informing environments and delivery systems is that a task needs to be accomplished. The task defines what information is needed. This task completion component typically involves a person" (Chapter 2; Cohen, 1999).

This chapter focuses on the usability of e-learning courseware (the delivery system) – one of the three interrelated components of the e-learning system. The system has two other components: the learner (the client) and the e-learning (the informing environment). The purpose of the e-learning courseware (the delivery system) is to support the implementation of e-learning (the informing environment) in order for the learner (the client) to learn.

Building on a stream of previous literature regarding the usability properties that are fundamental to the e-learning courseware, this chapter attempts to empirically assess users' current and perceived views regarding the usability of e-learning courseware.

E-Learning

E-learning, a new paradigm of distance education, is reshaping teaching and learning. Perhaps the most comprehensive definition of e-learning has been offered by Learnframe (2001) in which it states that e-learning is "using electronic applications and processes to learn. E-learning applications and processes include Web-based learning, computer-based learning, virtual classrooms, and digital collaboration. Content is delivered via the Internet, intranet/extranet, audio or video tape, satellite TV, and CD-ROM."

Adkins (2002) predicted that U.S. e-learning industry revenues will total $83.1 billion by 2006. This amount was divided among the following categories: K-12 academic $11.0 billion; higher education $23.0 billion; recruiting and staffing $4.6 billion; corporations and business $16.4 billion; government $2.7 billion; e-learning simulation $6.1 billion; vocational $8.6 billion, consumer $7.3 billion; and associations $3.4 billion.

Based on Adkins' (2002) report, it is evident that e-learning is expected to become increasingly popular. Perhaps less evident is e-learning's ability to deliver a quality educational experience. Given this sentiment, e-learning instructional design aspirations must be to enhance and optimize learning. Instructional design in general is planning and constructing successful and valuable instructional materials. Instructional design relies on learning models and theories to optimize learning. Broderick (2001) states that "Instructional Design is the art and science of creating an instructional environment and materials that will bring the learner from the state of not being able to accomplish certain tasks to the state of being able to accomplish those tasks." Instructional design has been developed that draws on learning theories and models including behaviorist, cognitive, humanist, constructivist, mastery learning and taxonomy, psychological stages in life cycle, multiple intelligence, and andragogy (pedagogy for adults).

There is consensus among scholars that instructional design for e-learning necessitates the use of appropriate learning models geared explicitly to the needs and specifications of learners (Egbert & Thomas, 2001; Pimentel, 1999; Randall, 2001). The importance of including appropriate learning models in designing e-learning curriculum has been widely acknowledged in previous research (Gold, 2001; Huang, 2000, 2002, Koohang & Durante, 2003; Pimentel, 1999; Sherry & Morse, 1995).

In addition, there are certain key elements that influence learning within the e-learning environment. These are learner consideration, learning task, learning content, content organization, instructional strategies, media, learning environment, quality assessment of instruction, selection of materials for delivery, and evaluation/feedback (Moore & Kearsley, 1996; Sherry & Morse, 1995; Simonson, Smaldino, Albright, & Zvacek, 2000).

The e-learning instructional design process, however, has primarily focused on insertion and or adaptation of learning principles/theories, and learning models into the e-learning curriculum. Little research has been done regarding the usability of e-learning courseware and its significance in the e-learning instructional design process. Koohang and du Plessis (2004) constructed a three element e-learning instructional design process model that includes not only the elements of instructional design as expressed by content and learning as expressed by user characteristics, but it also includes usability properties as expressed by system features. The authors believe that inclusion of usability properties within the e-learning instructional design process is vital to successful e-learning curriculum. In addition, recent studies by Mehlenbacher (2000), Koohang & Weiss (2003), and Koohang (2004) have revealed the importance of including usability into the e-learning instructional design process. Furthermore, Crowther & Keller (2004) assert that including usability as a part of evaluation improves the quality and effectiveness of Web-based instruction.

Usability, Usability Attributes, and Usability Properties

In general, *usability* is the extent to which a product or a system enables users to achieve specified goals. Usability is the ability of a product or system to effectively and efficiently fulfill the needs and specifications of users. Usability is essential to user satisfaction and user acceptance of a product or system. It is the measure of the quality of the user's experience when interacting with a product or system (Dumas & Redish, 1993; Guillemette, 1989; Nielsen 1993, 2000; Rosenbaum, 1989; Rubin, 1994; Shackel 1991).

Usability attributes are the outcome of a usable product or system. In other words, if a system is usable, one should experience both objective and subjective usability attributes. The objective usability attributes are effectiveness, learnability, flexibility, understandability, memorability, and reliability. The subjective usability attributes include positive attitude, user satisfaction, and product/system attractiveness (International Organization for Standardization [ISO], 1998; International Organization for Standardization /International

Electrotechnical Commission [ISO/IEC], 1991; Nielsen, 1993; Shackle, 1991).

Let's examine these attributes (adapted from Koohang & du Plessis, 2004) within the framework of Informing Science – the client/clientele (the learner), the delivery system (the e-learning courseware), and the informing environment (e-learning):

Effectiveness: The delivery system is effective if the client/clientele completely accomplishes a given task with accuracy and precision within the informing environment.

Efficiency: The client/clientele becomes efficient in using the delivery system if he or she has gained adequate skills and ability to perform a given task within the informing environment.

Flexibility: The delivery system is fully adaptable to variation and changes in tasks within the informing environment. It allows the client/clientele to become accustomed to changes that are given in various tasks.

Learnability: In the informing environment, the delivery system creates client/clientele learning in a short amount of time leading to easily accomplish tasks.

Memorability: In the informing environment, the delivery system causes the client/clientele to remember how to use the system without reiterating the learning cycle.

Operability: In the informing environment, the client/clientele is able to operate and control the delivery system with ease.

Understandability: The client/clientele easily understands the aptness of the delivery system in accomplishing a given task within the informing environment.

Reliability: Within the informing environment, the delivery system is reliable and dependent enough for the client/clientele to accomplish tasks.

Attitude & Satisfaction: Attitude & Satisfaction attributes refer to the degree of the client/clientele approval, pleasure, happiness, fulfillment, contentment, agreement, liking, comfort, appreciation, and enjoyment of/with the delivery system within the informing environment.

Attractiveness: Attractiveness is the ability of the delivery system to attract and draw client/clientele's attention within the informing environment. It also addresses the aesthetic satisfaction that the delivery system provides the client/clientele within the | informing environment.

To achieve usability attributes, *usability properties* must be designed into the product or system. Usability properties are inherent to user interface design and make a product or system usable (Dumas & Redish, 1993; Guillemette, 1989; Holms, 2002, ISO; 1998; ISO/IEC, 1991; Nielsen 1993, 2000; Rosenbaum, 1989; Rubin, 1994; Shackel 1991). The usability properties are delineated in the next section.

The Study

Koohang (2004) stated that usability of e-learning courseware is a critical aspect of the e-learning instructional design process. The author examined users' current perceptions toward e-learning courseware usability with 17 items that characterized e-learning courseware usability. The subjects of his study were 201 students enrolled in an accelerated undergraduate hybrid program. It was found that users' prior experience with the Internet and the amount of time they spent on the e-learning courseware were significant factors. In other words, subjects with more prior experience with the Internet had significantly higher positive perceptions toward the e-learning courseware usability. Similarly, subjects who spent more time on the e-learning courseware showed significantly higher positive perceptions toward the e-learning courseware usability.

The study sought to build on a stream of usability research conducted by Koohang (2004) and attempts to further achieve the following:

- Refine and expand the properties that characterize e-learning courseware usability (the delivery system) from 17 to 19 items. The additional 2 items are feedback and direction. These items were selected because e-learning courseware are inherently interactive and are used in an iterative fashion. The usability properties were taken from previous literature (Dumas & Redish, 1993; Guillemette, 1989; Holms, 2002; ISO, 1998; ISO/ IEC, 1991; Nielsen, 1993, 2000; Rosenbaum, 1989; Rubin, 1994; Shackel 1991). A list of the 19 usability properties follows:

    1. ***Simplicity***: The e-learning courseware (the delivery system) is uncomplicated, simple, and straightforward.

    2. ***Comfort***: The learner is comfortable using the e-learning courseware (the delivery system).

3. ***User-friendliness***: The e-learning courseware (the delivery system) is easy to use.
4. ***Control***: The learner is in control throughout the e-learning courseware (the delivery system).
5. ***Navigability***: The learner can easily get to where I want to go throughout the e-learning courseware (the delivery system).
6. ***Load/access time***: The learner dose not have to wait a long time for the pages to load.
7. ***Readability***: Within the courseware (the delivery system), the learner has no problem understanding the language used to present information.
8. ***Adequacy/Task Match***: Within the courseware (the delivery system), the information presented to the learner is enough. It is no more/no less than what he/she needs to know.
9. ***Link Visibility***: Within the courseware (the delivery system), the links throughout the e-learning courseware (the delivery system) are visible.
10. ***High color contrast***: The color contrast of the text is high throughout the e-learning courseware (the delivery system).
11. ***Appropriate font type and size***: The type and size of the fonts used to present information are appropriate throughout the e-learning courseware (the delivery system).
12. ***Well- organized***: The information in every page is well-organized and structured throughout the e-learning courseware (the delivery system).
13. ***Visual Presentation***: The visual presentation such as text boldfacing, italicizing, and underlining exist throughout the e-learning courseware (the delivery system).
14. ***Recognition***: The learner quickly recognizes the key points presented throughout the e-learning courseware (the delivery system).

15. ***Information relevancy***: The information presented is relevant to what the learner is supposed to learn throughout the e-learning courseware (the delivery system).
16. ***Right to the point information***: The information is concise and right to the point throughout the e-learning courseware (the delivery system).
17. ***Consistency***: There is consistency of appearance, terms, words, and action throughout the e-learning courseware (the delivery system).
18. ***Feedback***: The e-learning courseware (the delivery system) provides feedback.
19. ***Direction***: Directions on operating the e-learning courseware (the delivery system) are given when the client / clientele needs them.

- Use a different population sample (client/clientele): graduate students enrolled in an entirely on-line program as recommended by Koohang (2004); and
- In addition to examining e-learners' *current views* about the applied usability of their current e-learning courseware, also examines the *perceived importance* of e-learning usability design features held by e-learners.

The following are assessed: 1) users' current views about applied e-learning usability and 2) users' perceived importance of e-learning usability design features. Users' current views are important because they reveal what users believe about the usability of existing e-learning courseware. Users' perceived importance of e-learning usability is important to study since it reveals what users believe e-learning courseware ideally should be in respect to usability.

Recent studies of undergraduates in the area of Web-based distance learning have shown that increased experience with the Internet and more time spent using the e-learning courseware are closely associated with improved users' perceptions (Koohang, 2004; Koohang & Durante, 2003; Koohang & Weiss 2003). Therefore, the present study takes into consideration these two variables to determine whether similar results might be found using a graduate student sample.

Accordingly, this study will describe the characteristics of users' current views about applied e-learning usability and users' perceived importance of e-learning usability design features are designed. In addition, the following research questions (RQ) will be answered:

> RQ1: Does increased level of users' prior experience with the Internet influence their current views about applied e-learning usability?
>
> RQ2: Does greater amount of time spent by users on the e-learning courseware influence their current views about applied e-learning usability?
>
> RQ3: Does increased level of users' prior experience with the Internet influence their perceived importance of e-learning usability design features?
>
> RQ4: Does greater amount of time spent by users on the e-learning courseware influence their perceived importance of e-learning usability design features?

Study Methodology

Instrument

The instrument used in this study includes two measuring parts: 1) users' current views about applied e-learning courseware usability and 2) users' perceived importance of e-learning usability design features. (The Appendix shows the instrument.)

Users' current views about e-learning courseware usability part of the instrument was originally designed and validated by Koohang (2004). As previously noted, the present study adapted and refined this instrument by expanding the original 17-item scale to 19 items, done with the assistance from a panel of experts that consisted of four university professors who had extensive experience in the field of information science and information technology. The two additional items were feedback and direction. Since e-learning courseware are interactive and are used in an iterative manner, the provision of feedback and directions are key usability properties that need to be examined. The panel of experts concluded that all 19 items represent usability properties that are inherent to e-learning courseware.

A five-point Likert scale was used to assess each e-learning usability property for users' current views about applied e-learning courseware usability. The scale's descriptors were strongly agree = 5, agree = 4, neither agree nor disagree = 3, disagree = 2, and strongly disagree = 1.

To examine users' perceived importance of e-learning usability, a similar scale was developed based on the 19 usability properties. For this portion of the instrument the scale's descriptors were: 5 = Very Important, 4 = Important, 3 = Somewhat Important, 2 = Slightly Important, 1 = Not Important at all.

It must be noted that the two scales share parallel structure and utilize the same 19 usability properties inherent to the usability of e-learning courseware. The parallel nature of the scales allows evaluation of sets of user views in different cognitive structure. The users' current views about the usability of e-learning courseware scale is intended to tap current views held by e-learners in regard to applied e-learning courseware usability. The perceived importance of e-learning usability scale is intended to tap design ideals held by e-learners.

Forty three graduate students independent of the sample of respondents used in the study itself were used to further ensure the reliability of the instrument. The calculated coefficient alpha reliability from the results for users' current views about applied e-learning courseware usability and users' perceived importance of e-learning usability design features were .95 and .97 respectively. These results suggest that the instrument is stable enough and provides suitable consistency.

Participants & Procedure

Data were collected electronically via the Internet from 101 graduate students enrolled in an interdisciplinary information science graduate e-learning program at a large state university in the Midwest, USA. The subjects were males and females with different ages from various states within the USA. At the time of data collection, the subjects were taking courses such as Microcomputer Information Resources Management, Information Marketing, Information Retrieval/Storage Systems, Knowledge Management, and XML programming. The program consisted of 36 semester credits. It was completely on-line and used a popular e-learning platform to deliver instruction via the Internet. The program used state-of-the-art technology to support the e-learning instruction. For example, asynchronous audio and video streaming, presentation software, and live synchronous video lectures/office hours were used to support the delivery of e-learning.

The subjects were advised that their participation in the study was voluntary. All participants were 18 years or older. The subjects were guaranteed anonymity with regard to the publication of the results.

Data Analyses

Descriptive analyses were conducted on collected data to describe the characteristics of users' current views about applied e-learning courseware usability and users' perceived importance of e-learning usability design features. To answer the research question, collected data were analyzed by conducting six separate one-way analysis of variance (ANOVA) The one-way ANOVA technique produces a one-way analysis of variance for a quantitative dependent variable by a single factor -- independent variable. ANOVA tests the hypothesis that several means are equal. The predetermined level of significance (alpha = .05) was chosen.

Study Results

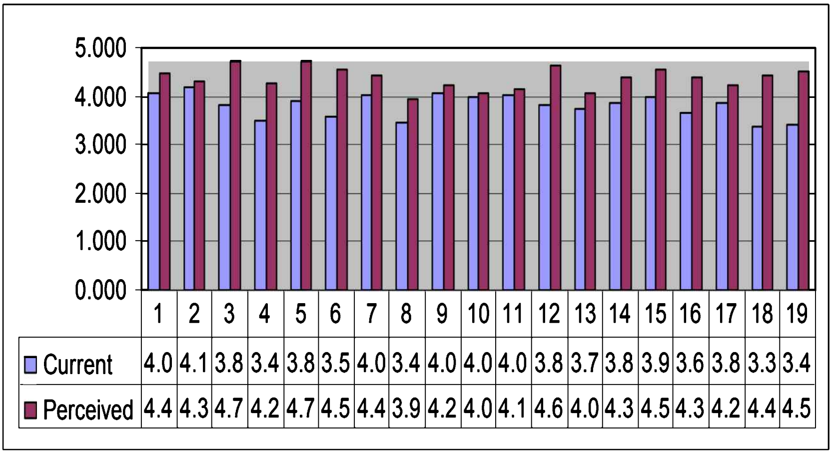
Descriptive

Table 1 includes the mean score and standard deviation for each e-learning usability property for both users' current views about the actual usability design of an e-learning courseware and the users' perceived importance of e-learning courseware usability. All items were above the mid-point of the five-point scale. The total mean score for users' current views about the actual usability design of an e-learning courseware was 3.80. The total mean score for the users' perceived importance of e-learning courseware usability was 4.37.

Figure 1 shows a graphic representation of users' current views about the actual usability design of an e-learning courseware (first bar) and users' perceived importance of e-learning usability (second bar). The mean scores for all usability properties were higher for users' perceived importance of e-learning usability.

Table 1: Descriptive for Users' Current Views & Perceived Importance

		Current Views		**Perceived Importance**	
E-Learning Usability Properties	N	Mean	SD	Mean	SD
Simplicity	101	4.050	0.712	4.475	0.642
Comfort	101	4.178	0.477	4.317	0.706
User-friendliness	101	3.832	0.813	4.713	0.516
Control	101	3.485	0.945	4.267	0.786
Navigability	101	3.891	0.969	4.703	0.501
Load/access time	101	3.574	1.003	4.545	0.625
Readability	101	4.020	0.774	4.426	0.622
Adequacy/Task Match	101	3.446	1.024	3.960	0.799
Link Visibility	101	4.079	0.560	4.218	0.657
High & readable color contrast	101	4.000	0.812	4.069	0.803
Appropriate font type and size	101	4.030	0.727	4.139	0.762
Well organized	101	3.832	0.825	4.644	0.502
Visual Presentation	101	3.733	0.882	4.069	0.738
Recognition	101	3.851	0.753	4.376	0.598
Information relevancy	101	3.970	0.685	4.564	0.518
Right to the point information	101	3.644	0.923	4.386	0.583
Consistency	101	3.842	0.914	4.238	0.750
Feedback	101	3.356	1.045	4.436	0.623
Direction	101	3.406	1.051	4.525	0.540



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Current	4.0	4.1	3.8	3.4	3.8	3.5	4.0	3.4	4.0	4.0	4.0	3.8	3.7	3.8	3.9	3.6	3.8	3.3	3.4
Perceived	4.4	4.3	4.7	4.2	4.7	4.5	4.4	3.9	4.2	4.0	4.1	4.6	4.0	4.3	4.5	4.3	4.2	4.4	4.5

Figure 1: Users' current views and their perceived importance compared.

1 = Simplicity, 2 = Comfort, 3 = User-friendliness, 4 = Control, 5 = Navigability, 6 = Load/access time, 7 = Readability, 8 = Adequacy/Task Match, 9 = Link Visibility, 10 = High & readable color contrast, 11 = Appropriate font type and size, 12 = Well organized, 13 = Visual Presentation, 14 = Recognition, 15 = Information relevancy, 16 = Right to the point information, 17 = Consistency, 18 = Feedback, 19 = Direction

One-way ANOVAs

RQ1: Does increased level of users' prior experience with the Internet influence their current views about applied e-learning usability? The results of ANOVA for users' prior experience with the Internet yielded a significant difference for users' current views about the e-learning usability ($F_{1,\ 99}$ = 12.176, p = .001). Increased level of users' prior experience influenced users' current views about the applied e-learning usability.

RQ2: Does greater amount of time spent by users on the e-learning courseware influence their current views about applied e-learning usability? The results of ANOVA for the amount of time spent on the e-learning courseware showed a significant difference for users' current views about the e-learning usability ($F_{2,\ 98}$ = 15.092, p = .000). Greater amount of time users spent on the e-learning courseware influenced users' current views about applied e-learning usability.

RQ3: Does increased level of users' prior experience with the Internet influence their perceived importance of e-learning usability design features? The results of ANOVA for users' prior experience with the

Internet yielded a significant difference for users' perceived importance of e-learning usability design features ($F_{1, 99}$ = .579, p = .449).

RQ4: Does greater amount of time spent by users on the e-learning courseware influence their perceived importance of e-learning usability design features? The results of ANOVA for the amount of time spent on the e-learning courseware showed a significant difference for users' perceived importance of e-learning usability design features ($F_{2, 98}$ = 5.613, p = .005). Greater amount of time users spent on the e-learning courseware influenced users' perceived importance of e-learning usability design features

Means and standard deviations for prior experience with the Internet, and the amount of time users spent weekly on the e-learning courseware are shown in Tables 2 and 3.

Table 2: Users' Prior Experience with the Internet

		N	Mean	SD
Users' Current Views	3 - 5 Years	22	3.486	0.350
	Over 5 Years	79	3.886	0.505
	Total	101	3.799	0.502
Users' Perceived Importance	3 - 5 Years	22	4.316	0.287
	Over 5 Years	79	4.380	0.368
	Total	101	4.366	0.352

Table 3: Amount of time spent on the e-learning courseware

		N	Mean	SD
Users' Current Views	Less than hours	18	3.383	0.251
	4 - 6 hours	31	3.681	0.421
	More than 6 hours	52	4.013	0.502
	Total	101	3.799	0.502
Users' Perceived Importance	Less than 4 hours	18	4.231	0.320
	4 - 6 hours	31	4.263	0.353
	More than 6 hours	52	4.475	0.332
	Total	101	4.366	0.352

Discussion

The ability to compare and contrast usability properties set in two cognitive frames, users' current views of e-learning courseware usability and users' perceived importance of e-learning courseware usability is a powerful analytical tool. That is, experienced usability can be assessed and perceived usability importance can be assessed. Differences between the two usability bases then can be analyzed and addressed.

In the present study e-learners perceive that their overall actual e-learning user experience is adequate, as indicated by a combined mean of 3.80 for the e-learning usability properties. However, e-learners desire improved usability. This desire for improved usability is indicated by a combined mean of 4.37 for users' perceived importance of these same properties.

Since the two survey instruments employed in this study share parallel construction, direct comparison of all usability properties is possible. In the case of all usability properties e-learners' perceptions of their actual experience is below these same learners' desired levels of usability.

The ability to compare and contrast usability properties set in different cognitive frames becomes a powerful design tool. That is, users' experiential reports and perceptual ideals allow targeted improvements of particular usability properties to be made.

For e-learning instructional designers, this study suggests a clear means to guide e-learning usability improvements. First, the e-learning usability properties have been acknowledged. Attention to these usability properties may result in a product with higher effectiveness, learnability, flexibility, understandability, memorability, reliability, user positive attitude, user satisfaction, and product/system attractiveness. Second, gaps between users' current views of e-learning usability and users' perceived importance of these same properties serve to focus remedial improvement efforts.

One of the key points in this study is the importance of the user involvement in the design process. E-learning design must shift from a programmer-perspective to a learner-perspective. That is, programmers/instructional designers must incorporate e-learners' experiential and perceptual feedback to build better-designed e-learning courseware.

This study found that users' (in this case graduate students') prior experience with the Internet and time spent using e-learning courseware is associated with higher reported levels of e-learning courseware usability. Thus, it appears that facility with the Internet usage and the e-learning itself positively influence users' perceptions of their experiences with e-learning courseware.

While this alone is a powerful finding, it is consistent with prior research reports (Koohang, 2004) As in the current study, facility with the Internet usage and time spent using e-learning courseware were positively associated with reported levels of e-learning courseware usability. Consequently, the current study asserts that the concept of usability is multi-dimensional with experience being the new dimension. The experience dimension clearly can improve usability design.

User-related attributes such as users' prior experience with the Internet and time spent using e-learning courseware have theoretical importance as well. Koohang and du Plessis (2004) constructed a three element e-learning Instructional Design Process Model. The model consists of instructional design as expressed by content, usability as expressed by system features, and learning as expressed by user attributes. While the e-learning instructional design process model specifies system features, user attributes are treated as a black box and are not specified. Therefore, based on the weight of consistent and repeated research findings, prior experience with the Internet and e-learning courseware experience are two key components describing the user and his or her readiness to learn, and should be included in the model. Finally, higher levels of e-learner facility with the Internet and the e-learning courseware itself should result in better e-learning outcomes. According to theories of cognitive psychology (Howard, 1983), humans store procedures of automatic processing and controlled processing in long-term memory. These processes differ in their requirements of access to working memory (to use a computer analogy, a limited capacity central processor). Automatic processing of a skill does not require the use of working memory for execution and thus does not interfere with the controlled process of learning new information. Therefore, e-learners who already have a high degree of the Internet and e-learning facility can concentrate on the course's content and not on the arcane nature of the e-learning's design. More mental energy can be expended on learning the subject matter not the medium and vehicle of delivery.

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Appendix

E-learning Courseware Usability Survey

The purpose of this survey is to gather information about e-learners' perceptions toward e-learning courseware usability. Please take a few minutes to complete this survey based on your experience with the e-learning courseware you have been using for your distance education course(s).

Please do not leave any questions or statements blank.

Notes:

1) Your participation in completing this survey is absolutely voluntarily.
2) You must be 18 years or older to complete this survey.
3) All your responses are kept confidential. Do not put your name on this survey.

SECTION 1
Please answer the following questions by circling the appropriate number:
Gender:
(1) Male
(2) Female

Years of Experience with the Internet:
(1) 1 – 2 Years
(2) 3 – 5 Years
(3) Over 5 Years

I spend an average of ____ hours/week on the Web-based Platform:
(1) Less than 4 hour
(2) 4 - 6 hours
(3) More than 6 hours

SECTION 2
Using the scale below, please indicate your response to each of the statements regarding the usability of the e-learning courseware you use for e-learning course(s).

SCALE:
5 = Strongly Agree, 4 = Agree, 3 = Neither Agree nor Disagree, 2 = Disagree, 1 = Strongly Disagree

1. ***Simplicity***: The e-learning courseware is uncomplicated, simple, and straightforward.
   5 4 3 2 1
2. ***Comfort***: I feel comfortable using the e-learning courseware.
   5 4 3 2 1
3. ***User-friendliness***: The e-learning courseware is easy to use.
   5 4 3 2 1
4. ***Control***: I feel in control throughout the e-learning courseware.
   5 4 3 2 1
5. ***Navigability***: I can easily get to where I want to go throughout the e-learning courseware.
   5 4 3 2 1
6. ***Load/access time***: I don't have to wait a long time for the pages to load.
   5 4 3 2 1
7. ***Readability***: I have no problem understanding the language used to present information.
   5 4 3 2 1
8. ***Adequacy/Task Match***: The information presented is enough. It is no more/no less than what I need to know.
   5 4 3 2 1
9. ***Link Visibility***: The links throughout the e-learning courseware are visible.
   5 4 3 2 1
10. ***High color contrast***: The color contrast of the text is high.

5 4 3 2 1

11. ***Appropriate font type and size***: The type and size of the fonts used to present information are appropriate.

5 4 3 2 1

12. ***Well- organized***: The information in every page is well-organized and structured.

5 4 3 2 1

13. ***Visual Presentation***: The visual presentation such as text boldfacing, italicizing, and underlining exist.

5 4 3 2 1

14. ***Recognition***: I quickly recognize the key points presented throughout the e-learning courseware.

5 4 3 2 1

15. ***Information relevancy***: The information presented is relevant to what I am supposed to learn.

5 4 3 2 1

16. ***Right to the point information***: The information is concise and right to the point.

5 4 3 2 1

17. ***Consistency***: There is consistency of appearance, terms, words, and action throughout the e-learning courseware.

5 4 3 2 1

18. ***Feedback***: The e-learning courseware provides feedback.

5 4 3 2 1

19. ***Direction***: Directions on operating the e-learning courseware are given when I need them.

5 4 3 2 1

SECTION 3

Using the scale below, please rate the importance of each of the usability properties to your use of the e-learning courseware.

SCALE:

5 = Very Important, 4 = Important, 3 = Somewhat Important, 2 = Slightly Important, 1 = Not Important at all

1. The importance of **Simplicity** (Simple & straightforward to use)

5 4 3 2 1

2. The importance of **Comfort** (Being at ease with the e-learning courseware)

5 4 3 2 1

3. The importance of **User-friendliness** (User-friendly, easy to use e-learning courseware)
   5 4 3 2 1
4. The importance of **Control** (User being in control of e-learning courseware)
   5 4 3 2 1
5. The importance of **Navigability** (Being able to easily move around throughout the e-learning courseware)
   5 4 3 2 1
6. The importance of **Load time** (Not having to wait a long time for information to load)
   5 4 3 2 1
7. The importance of **Readability** (understanding the language used to present information)
   5 4 3 2 1
8. The importance of **Adequacy/Task Match** (enough information, no more, no less)
   5 4 3 2 1
9. The importance of **Link Visibility** (visible links)
   5 4 3 2 1
10. The importance of **High color contrast** (High color contrast for presenting information)
    5 4 3 2 1
11. The importance of **Font type and size** (Appropriate font type and size)
    5 4 3 2 1
12. The importance of **Well-organized** (Well-organized and structured)
    5 4 3 2 1
13. The importance of **Visual Presentation** (Presence of text boldfacing, italicizing, and underlining)
    5 4 3 2 1
14. The importance of **Recognition** (Being able to quickly recognize the key points)
    5 4 3 2 1
15. The importance of **Information relevancy** (Relevant information)
    5 4 3 2 1
16. The importance of **Right to the point information** (brief, short, and right to the point information)
    5 4 3 2 1

17. The importance of **Consistency** (consistency of appearance, terms, words, actions)

    5 4 3 2 1

18. The importance of **Feedback** (Providing feedback to users)

    5 4 3 2 1

19. The importance of **Direction** (Providing direction to users)

    5 4 3 2 1

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Chapter 6

Information and Informing Science

Karl T. Knox

Abstract

There are identified a number of notions regarding the term information. This chapter will explore these sometimes-conflicting notions of information and the reason why they occur as the result of different perspectives and understanding of that term. Initially, within the discourse two camps are identified, firstly, those who identify information as a resource and secondly, those who identify information as a processual approach enacted by individuals. The first notion is not uncommon within the business environment and has gained acceptance due to the movement known as 'information resource management'. The second approach recognises the involvement of individuals or more succinctly human understanding and interpretation, but is not necessarily one that is addressed within the business world.

The fact that information is a foundational concept within informing science movement highlights its significance; therefore offering an opportunity to apply the concept of information to the informing science framework.

Introduction

From the middle of the 20th century through the beginning of the 21st century most organisational activity has been inextricably linked to the knowledge economy.

Dhillon (2001: 170) and JISC (1998) both acknowledge that *information is the lifeblood of any organisation* and as such the time has come to give information its place within organisations. Despite its importance, however, information is a term that is commonly used and accepted but rarely understood or interpreted consistently. Unfortunately, this creates a situation where individuals frequently find themselves discussing different ideas, understandings or interpretations without really knowing or realising it. Failing to consider the nature and importance of information has long been recognized as a weakness in information technology (IT) research as Davenport (2000: 5) argues, previous *investigations* [into the notion of information] *have focused on the 'T' Technology in information technology and not the* ***'I' Information.***

This classic misalignment of focus is not unique to the IT discipline but can be found within other areas.

A similar ambiguity can be found within the research literature. Here, particular perspectives, such as positivism versus interpretativism, hold implicitly different views without necessarily recognizing these differences when it comes to the research process. Bawden (2001: 1) asserts the ambiguity in the use of the term information has resulted in *different meanings in different contexts and communities of discourse and provides an excellent example of Wittgenstein's (1958) language game.* That is, multiple uses imply multiple meanings, all of which create confusion and a general apathy towards the term that is in fact a cornerstone of many organisations operations and environments (given the information society/economy). The central objective of this chapter is therefore to clarify these perspectives on information.

In this chapter, the goal of clarifying what is meant by the term information is particularly focused on applications in the informing science transdiscipline. The chapter therefore begins by considering the role played by information within the informing science framework, which serves as a useful tool for exploring the concept. The next topic involves identifying whether information is viewed as a resource or a process. Understanding these two perspectives then becomes an ongoing thread throughout the chapter. Next to be considered is the important relationship between data, information and knowledge. Once again, considerable divergence is encountered. Finally, ontological and epistemological perspectives on information are explored, where—unsurprisingly—differing schools propose very different views.

The chapter makes no attempt to specify a 'proper' definition of information, although conceptual and practical weaknesses in the most commonly encountered definitions are explored. In concluding, however, it is noted that establishing a common understanding of these perspectives is critical if informing science is to advance, even if that understanding is limited to recognizing the alternative perspectives when they are encountered.

The Informing Science Framework

The informing science framework (see Chapter 2) considers three distinct areas: the informing environment, the delivery system, and the task-completion system (Figure 1). Although, it is acknowledged that this framework is an amalgamation of other models there is within all of the models an unspoken, accepted notion of something that they would term information.

What follows is a discussion of the framework in relation to the notion of information.

The Informing Environment

The Informing Environment (IE): Characterizes the three levels of analysis that apply to an informing system. These levels are as follows:

- The instance - using an informing system that is in place
- The creation of new instances of informing systems (to the organisation or any of its components)
- The creation of new designs for informing systems

We now consider how information is perceived at each of these levels.

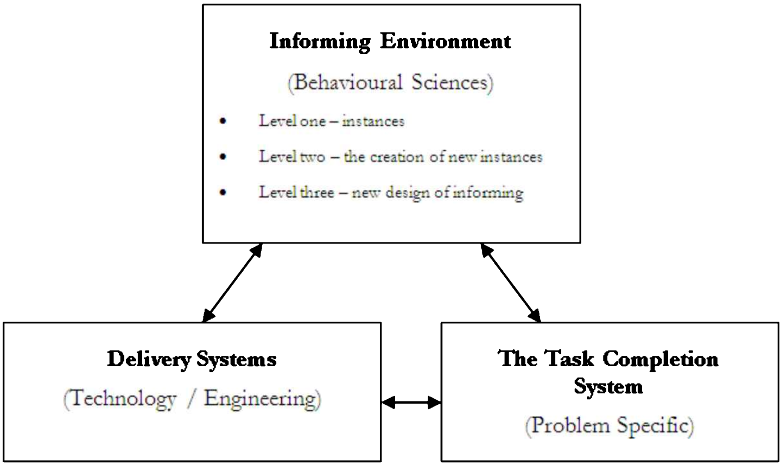

Figure 1: The Informing Science Framework

What follows is a discussion of the framework in relation to the notion of information.

Level 1 – the instance – using what is in place

Within this fairly basic model there is a notion of transmission of information – how and by what means does this occur? At the instance level, the informing environment is focusing on the actual information itself, that is, at the most basic level what information is currently available to users, in what format and how often. This is often the case organisations find themselves in whereby they use what is already there; unfortunately, this may not be appropriate and may just perpetuate the same problem, i.e., this is the way we have always done it, or this is how we receive our reports – therefore using the available and current information within the organisation, without actually questioning is this information appropriate, accurate for ones needs or relevant. Often individuals within organisations manipulate, re-format, or alter the information they receive to meet their needs and requirements.

Level 2: the creation of new instances

The use of information at this level may relate to bringing in new ideas but still being constrained to a certain degree, i.e., to all intents and purposes much of the information that is available within organisation is constrained by the procedures and practises that are inherent within the organisation. There may be new ideas on how to approach the problem but information is still collected, distributed and used in the same way; therefore the ideas are new but the information upon which they are developed is not new.

Level 3: the creation of new designs for informing

The use of information at this level requires a back to basics approach whereby it is the very questions one asks that are the foundation for development. Therefore, the issue is about what is collected in the first place, how is it collected, what is needed and what it is intended to be used for, as well as who wants it and it what format are an attempt to move back to basics. Understanding what one wants to do with the information and why, requires a greater understanding of the processes, the activities and the needs of the organisation. It is at this level, within the 'Informing Environment' that the question of 'What is information?' comes to the forefront and information itself becomes the important issue not constrained by previously held views within the organisation, whether they be what is currently available or what systems are currently in place.

The Delivery System

The delivery system refers to the mechanism by which information is transferred. An implication of the delivery system concept is therefore that information can be shared, meaning that it is codifiable, tangible and easily shared. The delivery system is generalizable to other forms of communication, such as voice and personal contact. In fact, in the original communication model (upon which the informing science framework draws) Shannon (1949), acknowledge the basic role of the individual via the sender, receiver, encoder, decoder elements whereby the model's raison d'être is an attempt in reducing uncertainty. However, equating the notion of information with a delivery system may lead to an underlying assumption that technology is necessarily involved.

The Task Completion System

The task-completion system places the emphasis on the tasks that need completing, with the informing environment and the delivery system elements of the framework working together to address the information needs of the tasks to be accomplished. It is the tasks that define what information is required; therefore, the author would suggest, at this stage, that the emphasis is placed upon the individual who requires a level of understanding and knowledge about that task, typically referred to as the client. It is the client's level of understanding and knowledge that will dictate what is required to accomplish the task. What seems to be a major fact of this aspect of the informing science framework but to-date has not necessarily been identified is the notion of information literacy. That is, information literacy requires as Brehens (1994: 317) argues a recognition of *knowing when there is a need for information; identifying the information needed in order to address the problem; finding the needed information; evaluating the located information; organising the information; and using the information effectively to address the problem.* This, the author suggests encapsulates the notion of what the task completion system aspect of the informing science framework is addressing and is much more than the 'task defines what information is needed'. Rather; it places the emphasis on the individual client involved in the process. It is that client's understanding, knowledge and level of skill that will determine what information is needed, where to find it, what questions to ask to acquire it and ultimately how to analyse it and act upon it in order to reduce uncertainty and make decisions.

Overview of Information and the Informing Science Framework

What becomes evident within the Informing Science Framework is that 'information' plays a major part in all aspects as the conduit for the notion of 'informing' to work. What can be added to this framework, and to many other frameworks (MIT model – Scott-Morton, 1992; Socio-Technical model –Eric Trist and the Tavistock Institute, 1958; and/or SECI model – Nonaka and Takeuchi, (1995)) that imply that the notion of information is contained within them is a need to clarify what 'information' means to that particular framework and how it can be best utilised and/or understood within that context. This is in part what Figure 2 identifies i.e. the relationship between information and the informing science framework; it identifies each element and then relates it to the notion of information as discussed throughout the following paragraphs.

In Figure 2, the author views the informing environment aspect of the framework in a similar fashion to the work of Shoshana Zuboff's (1988) 'in the age of the smart machine, approach where Zuboff identifies the terms **Automate**, **Infomate** and **Transformate** in relation to information systems. Automate relates to doing manual tasks faster, Infomate relates to the by-product that comes from using technology and Transformate relates to redesigning the whole process. In fact, this is very similar to the three levels of the informing environment whereby there is a need to identify what is already there, identifying new instances of informing thereby using or extracting more from what is already there i.e. using things differently and finally creating new systems are akin to trying to address completely new approaches to informing.

Given that one has viewed information in relation to the informing science framework it would seem appropriate to now discuss the notion of information by identifying the debates and discussions that create this complexity and ambiguity in relation to information

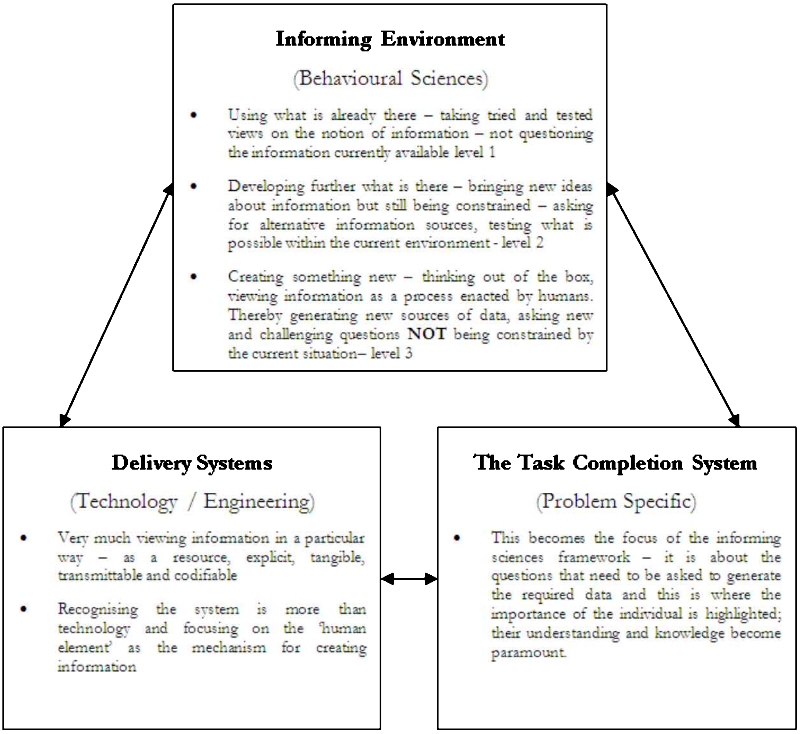

Figure 2: The Informing Science Framework in relation to 'information'

Information

Bawden (2001: 94) argues the *commonality of information has led to information becoming a central concept* in many disciplines. Figure 3 captures many definitions of information and perspectives relating to its impact. In fact, some researchers choose to avoid the issue altogether. For example, Eaton & Bawden (1991) state *we do not try to deal with the well-worked area of what is meant by information, nor do we try to distinguish between data, information, knowledge and wisdom.* More commonly, however, researchers decry the situation. They, for example (Collins 1997; Mutch 1997; Choo 1998; Mutch 1999; Hislop 2005; Knox 2007; Knox 2009) argue that the nature of information is misunderstood and poorly discussed. This, in turn, suggests that much of the problem revolves around gaining a clear workable definition of the term as a prerequisite to acquiring a better understanding of how to use, manage and create value from information.

Many organisations still relate their understanding of managing information to information technology and information systems. The

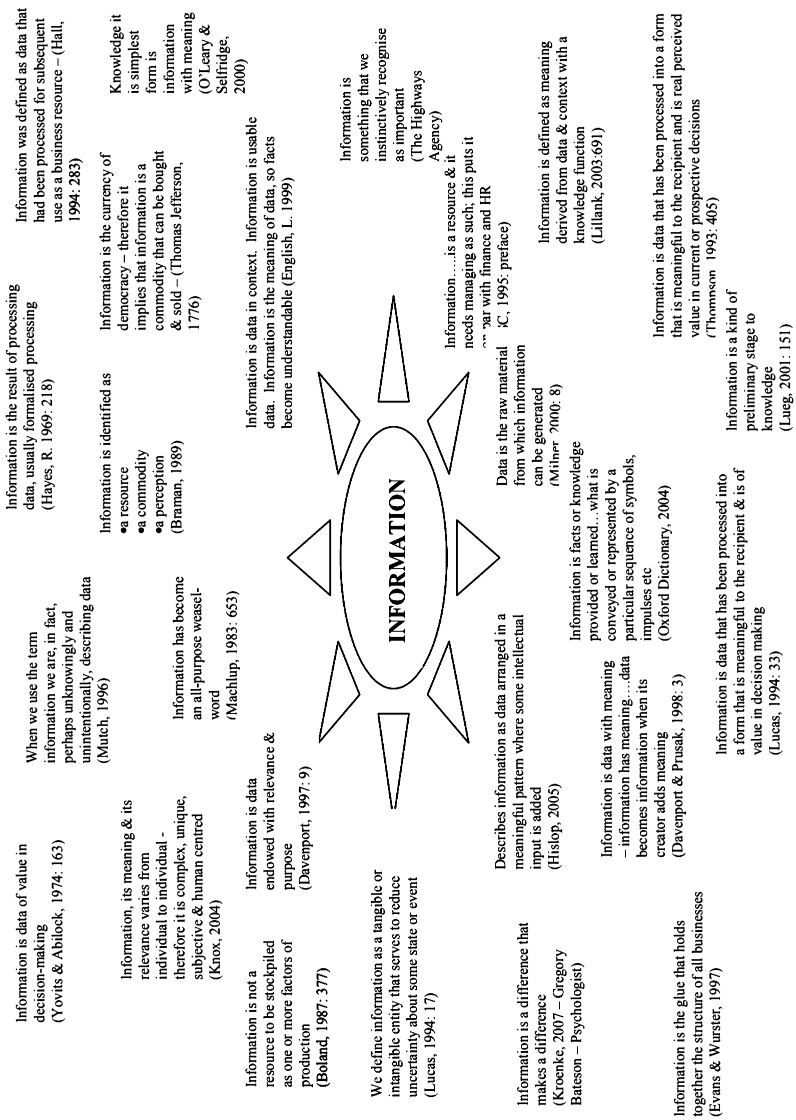

Figure 3: The Notion of Information

author would argue that when the notion of information of information is contextualised within the business environment these same organisations are asserting that:

- their systems do not provide them with the information they require, or
- they can't get to the information they really want, or
- their systems just don't do what they want them to do.

The business literature is strewn with examples of organisational failure due as a consequence of ineffective information systems. Given this common scenario it seems appropriate to reflect more carefully on the nature of information itself, and what role it plays. In particular, clarifying what we mean by information is an important prerequisite to addressing more fundamental questions, such as:

- What does information actually mean to those individuals who are using it?
- Is there a difference between data and information for this organisation?
- What data would assist in solving the current issue, situation or problem?
- What happens to the data throughout the organisation? Where does it go, who uses it, what processes build on it or contribute to it?
- How is data generated? How is it used within the organisation?
- How is information generated/created? What constitutes information?

The author has identified two broad categories within which the notion of information will be discussed: information as product and information as process. These categories represent two very different ends of a spectrum; in reality issues are very rarely so clearly separated. Nonetheless, characterising information in these two ways, as we shall now do, serves to highlight important differences in how the concept can be viewed.

Information as a Product

Historically, information has been presented as a structured form of data, Hall (1994) acknowledges in her research within the Scottish Textile Industry that *information was identified as data that had been produced for subsequent use as a business resource.* Taking this perspective, it then makes sense for individuals to value information much the way they would any other resource — in terms of its ability to transform companies and increase their competitive advantage within the market place. It therefore, seems logical to pose a series of questions to clarify what is meant by 'information as a product' and surface some of the implications of that perspective. These include:

1. Is information similar to other factors of production?
    - Information unlike other factors of production does not deplete with usage
    - Information does not decrease, in fact, it seems to be a grow and as such has become a vital concept to many organisations
2. What happens to information once it has been used?
    - Information actually becomes more important the more it is used, unlike other factors of production
    - Organisations become heavily reliant upon what the see as information to provide some form of differentiation or competitive advantage
3. What value can be derived from information? How can that value be measured?
    - The time element of information if highly important, that is, those who have it initially are seen to have an advantage over those who do not; and as such when it becomes common knowledge (or shared) its initial advantage is generally decreased, and
    - Finally, information itself implies nothing about the value that individuals or organisations can derive from it

In answering these questions, it is clear that information diverges quite considerably in its characteristics from those of many traditional organisational resources. This, in turn, raises questions as to the advisability of treating information purely in resource terms. Instead, as argued by Eaton & Bawden (1991), managing information as a resource may be a tenuous activity.

Information as a Process

An alternative view of information advocated by researchers such as Mutch (1996), Davenport (1997) Davenport and Prusak (1998), and Knox (2007) is to characterise information as a process and to pay particular attention to the role that human-beings play in creating information. This perspective is clearly demonstrated by Boland (1987), who asserts that *information is not a resource to be stockpiled as one more factor of production.[…] It is a skilled human accomplishment.*

If information is not a resource but a process, how does one make sense of it? One approach would be to view information in much the same way that accountants view goodwill or physical scientists view 'dark matter'. Accountants offer or place a value for 'goodwill' within a company's set of accounts but this is highly subjective, it can vary greatly and is often a contentious issue. Physical scientists acknowledge that 'dark matter' exists but they are unsure of where it is or how to measure it. In this alternative view, what is meant by information is inextricably tied to a process that is enacted by individuals and it is these individuals who make sense, place in context and act upon the result. A more conceptual definition is offered by Kroenke (2007), who refers to Gregory Bateson's view that *information is a difference that makes a difference.* In essence, this statement asserts that in reality there are differences, but only those that make a difference qualify as information. This places the emphasis of the individual in the information process as fundamental.

To reconcile the processual view of information with the previously discussed product view, we could assume the latter actually refers to data and not information. Some will argue that this is a semantic issue and not one of great concern. For example, Date (1986: 2) asserts that *the terms data and information are treated synonymously* [in many texts] highlighting that often they are used interchangeably. The problem with allowing that distinction to blur, regardless of the particular terminology, is that the resource and process views are quite different in both their epistemology and focus; i.e. the difference has important implications for organisations in their efforts to manage information and knowledge. Consider, for example, the following two well known articles written by Porter and Millar (1985) and Drucker (1995):

- Porter and Millar (1985) How Information gives you competitive advantage
- Drucker, P. (1995: 90) knowledge has become the key economic source and dominant – and perhaps even the only – source of competitive advantage

If information and knowledge are a resource, then the focus of organisational efforts would be on managing 'information' just as one would manage any other factor of production—which is to say controlling its inventory, getting the best price, ensuring appropriate warehouses are available, managing delivery and assuring its quality. Where a process perspective is taken, on the other hand, the focus necessarily shifts to managing the human side of the equation: Is learning taking place? Who knows what? Are technologies in place informing the users appropriate? Drucker, for example, argues that companies often do not know who their experts are and this creates scepticism of so-called knowledge management initiatives.

The process perspective asserts that 'information' and 'knowledge' are purely human centred activities and not ones that technology currently mimics. So information and knowledge cannot be stockpiled, they are not 'out there' waiting to be found and they can be interpreted as meaning different things to different people. This adds significantly to the complexity organisations face while trying to manage it.

How to Move Forward in Defining Information

If our understanding of information is to be advanced, much of the work required will need to be done through academic research. Unlike many topics that could be of interest to academics and practitioners alike, much of the work that needs to done to establish a firm grounding for the concept of information is highly abstract in nature. This abstraction could create a major obstacle to practitioner-instigated investigations, as suggested by the sidebar which follows.

- How many of us would be comfortable about asking our boss or the organisation they work for to spend time investigating and trying to understand their use of and interpretation of information. Especially if it was identified that information is a purely human attribute? It is either seen as:
    - Too trivial as everyone knows what is meant by the term information and what it pertains too, or
    - Simply too complex and they assimilate information with technology or systems or even data – therefore why bother!
- How many of us are able to identify what data we want, need or use
- How many of us could acknowledge that we have actually thought about what information means to us as an individual, or
- What is the information used for within the organisation and what is my role within that activity?

In reality, addressing these types of questions is not the type of task that many managers would undertake; this is particularly true given the focus on 'bottom line' figures, costs and return on investment strategies identified within many organisations. How would individuals cost this investigation? How would individuals show benefits, usually related to financial amounts? This, in the past, has been the impetus behind viewing information as a product and aligned information as a by-product or an outcome of technology; this amalgamation of the two (information and technology) is powerfully reinforced by the notion, promoted by the information management movement, that information is that which can be processed by a computer and as such places the value of information in terms of money spend on technology.

Given that the value of spending time clarifying the concept of information may not be immediately obvious to practitioners, the follow-on question would logically be: would such clarification offer value to anyone? Wilson (1986) supports this complexity by arguing that the common usage of the term is a problem. Wilson (1986) states *when we look more closely at the nature of information, that everyday certainty about its character disappears*. That is, this everyday use of the term and commonality creates much of the ambiguity and confusion. There is a use and misuse of the term within many disciplines, each one using it for their own particular purpose and need, as highlighted in **Figure 3**.

Data, Information and Knowledge

Within the information systems field Checkland and Holwell (1998) acknowledge that much of the literature exhibits *a confusion between basic concepts of data, information and knowledge* and more importantly *the relationship between* them. There is an indication that often terms are used interchangeably and/or are often not explained, creating an issue over clarity and meaning. Moreover, participants in an organisation's information systems may encourage some level of obfuscation, as a unit's role moving from data processing, to information systems, and then to knowledge management may be seen as becoming more important and intellectually advanced in the eyes of the organisation. This proposition is advanced by Machlup (1983) who states that *the people selling management information systems (MIS) feel better if they call the output of their systems information, that is, something of a higher order* (Machlup 1983: 648). What becomes apparent is that although there may have been a 'name change' and the departments may indeed have taken on more responsibilities, the bottom line is that they are still dealing with data and not information and/or knowledge. Thus, the very terms data, information and knowledge are terms which may become politicised. The relationship between these terms is now explored.

The Data-Information-Knowledge Hierarchy Perspective

One definition identified by Drucker (1999) refers to *information as data endowed with relevance and purpose.* English (1999) views the relationship between data and information as follows: *Information is data in context.*

Information is usable data. Information is the meaning of data, so facts become understandable. Thus, data is proposed to be the raw material from which information is derived.Lueg (2001) further argues that *information is a kind of preliminary stage to knowledge.* Chaffey & Wood (2005) characterise knowledge as being *the combination of data and information to which is added expert opinion, skills and experience to result in a valuable asset* *which can be used to make decisions*. Thus, information is proposed to be the source of knowledge.

Taken together, these relationships suggest the relatively straightforward hierarchy of data, information and knowledge pictured in Figure 4. The complete relationship is supported by researchers such as Davenport (1997), who states that *data are simple observations of states of the world, information is data endowed with relevance and purpose, and knowledge is valuable information* and Kent (1982: 315), who considers *transformations that result in data becoming information and knowledge*

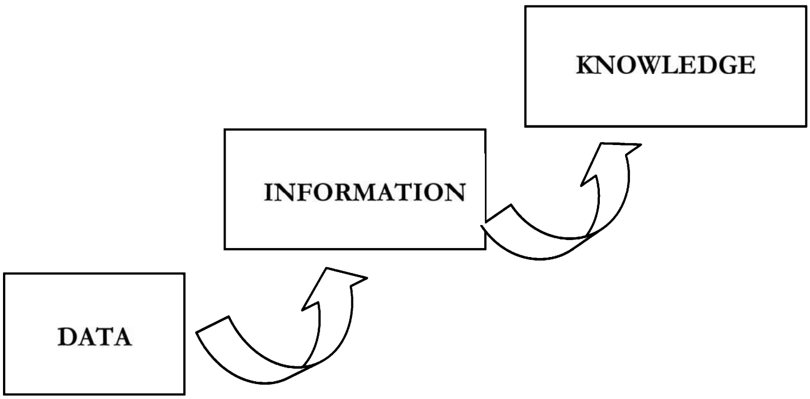

Figure 4: Presumed hierarchy of data, information and knowledge

Some examples of research supporting the data-information-knowledge hierarchy are summarized in Table 1.

Weaknesses in the Hierarchy View of Data, Knowledge and Information

Despite its widespread usage, there are strong arguments that can be advanced that such simplistic model impedes our understanding of the concepts. The core of the problem is that a linear perspective such as that presented in Figure 4—where each item feeds into the next—strongly tempts us towards the product view of information presented earlier. In doing so, it is easy to lose sight of the human element. Even proponents of the hierarchical perspective acknowledge this risk.

Table 1: Data, Information, Knowledge Distinction

Author	Data	Information	Knowledge
Davies & Ledington (1991) p4	Data consists of many individual bits/pieces/items or facts that can be simultaneously, or sequentially, processed to support the learning process	Information is not some object that exists in the world – information is part of the learning process – information has meaning according to the interpretation which is happening	No actual reference to the term knowledge
Drucker (1989) p46	Data is relatively easy to capture and does not necessarily require analysis	Information is data endowed with relevance and purpose	Knowledge, by definition, is specialised
Checkland & Holwell (1998) p88,	Data are checkable facts, that can be agreed, disputed both of which allow supporting evidence to be brought forward	This is data – capta that then has been enriched. i.e. related to other things, seen as part of a larger whole – gains significance	Larger structures of related information – expected to have longevity
Chaffey & Wood (2005, p21)	Discrete, objective facts about events. Data are transformed into information by adding value through context, categorisation, calculations, corrections, and condensation	Organised data, meaningful and contextually relevant. Used for decision making	The combination of data and information to which is added expert opinion, skills and experience to result in a valuable asset which can be used to make decisions

Boddy, Boonstra & Kennedy (2002, p6, 15) **Citing Martin et al, 1994, Turban, et al, 1999**	Refers to recorded descriptions of things, events, activities and transactions	Information is data that has been processed so that it has meaning and value to the recipient	No clear definition is offered except to state certain information systems help people to make decisions by incorporating human knowledge into the system
Hislop (2005) p13, 14 15 & 16	One could see data as being raw numbers, facts, images, words, sounds based on observation or measurement	Information represents data arranged in a meaningful pattern, data where some intellectual input has been added	Means to analyse / understand information / data, belief about causality of events / actions, and provides the basis to guide meaningful action and thought. That is one could say knowledge can be understood to emerge from the application, analysis and productive use of data and/or information
Davenport (1997) p9	Simple observations of the states of the world • easily structured • easily captured on machines • often quantified • easily transferred	Data endowed with relevance and purpose • requires some unit of analysis • need consensus on meaning • human mediation necessary • people turn data into information	Valuable information from the human mind, includes reflection, synthesis, context • hard to structure • difficult to capture on machines • often tacit • hard to transfer
Sources adapted from (Drucker 1988; Drucker 1989; Davies and Ledington 1991; Martin, DeHayes et al. 1994; Davenport 1997; Boddy, Boonstra et al. 2002; Chaffey and Wood 2005; Hislop 2005)			

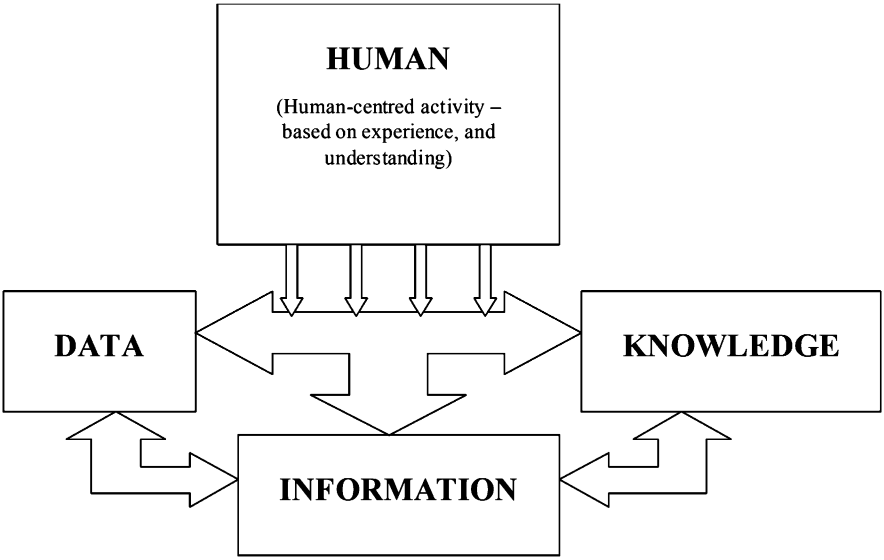

Figure 5: The Dynamic (and circular) Relationship between Data-Information-Knowledge and humans (Knox 2007)

The real weakness of the hierarchical approach has to do with the inherent circularity of the three terms. As illustrated in Figure 5, the human centred element in the process has the ability to ascribe meaning, interpretation and understanding. This limited view is acknowledged by Davenport and Prusak (1998) where they identify *that data is a set of discrete, objective facts about events…data describes only a part of what happened; it provides no judgement or interpretation that makes a difference…unlike data, information has meaning…data becomes information when its creator adds meaning.* At the same time, however, humans involved in the process can create data and information. Tuomi (2000), for example, argues that there is a reverse hierarchy of data – information and knowledge as *data emerges last – only after knowledge and information are available.* Representing the relationship as a one-way flow, i.e., data → information → knowledge totally fails to capture the richness of the informing processes. Indeed, it obscures them.

Philosophical Perspectives on Information

A further challenge to defining information is introduced by philosophy. Two particular perspectives on understanding are commonly introduced in this context: epistemology and ontology. The epistemological perspective considers the question of how we know about that world. For example, Denzin and Lincoln (1994) characterize the epistemological question as being *what is the nature of the relationship between the knower and the would-be knower and what can be known?* Hirschheim et al., (1995) define epistemology as the *nature of human knowledge and understanding that can possibly be acquired through different types of inquiry and alternative methods of investigation.* Within epistemology, three distinct schools—objectivism, subjectivism and constructionism—are frequently encountered. These are summarized in Table 2.

How an individual (e.g., the student, the researcher and the organisation) views the world strongly influences what the individual sees as being valid and acceptable knowledge. That perception, in turn, can have a profound effect on how that individual addresses the issue of information. This is not necessarily the place for a full-blown discussion on philosophy or philosophical issues, as stated above. What needs to be identified, initially, is that how an individual views or interprets the world can fall into a number of ontological interpretations.

Therefore, by taking different ontological views of the world and coupling them with relevant views of the world it is possible to identify how this in turn impacts on what individuals' and organisations can relate to as information. Outside of traditional philosophical disciplines, Tuomi (2000) states that *the existence of thorny epistemological issues is recognised but not discussed, and references to relevant literature outside the cognitivistic tradition are rarely made explicit.* Therefore, seeing them applied them to business like issues and discussing them in relation to business problems would be an unusual occurrence.

As an example of the types of challenges these philosophical perspectives raise, suppose we were to adopt the JISC (1995a) definition from Figure 3, asserting information is a resource and its needs managing as such; this puts it on par with finance and human resource management. There is an obvious assumption that 'information' is viewed in a very economic way, that is, it is just like the traditional economic resources of land, labour and capital. If information is taken in this way it could be inferred that information is an object; that it is factual and independent of anything else i.e. it exists outside of the mind (a realist ontology) and that meaning resides within that object (an objectivist epistemology) and therefore only information

Table 2: Ontological and Epistemological views in relation to information		
Ontological Perspectives	**Interpretation – in terms of information**	**Epistemological Perspectives**
Realism The notion that the world exists outside of the mind	Therefore information is a tangible object just waiting to be found, and can be discovered through objectivist approaches	**Objectivism** Meaningful reality exists as such apart from the operation of any consciousness, i.e. it is there waiting to be discovered
Idealism The notion that world exists only within the mind	The concept of information is imposed - this maybe based on dreams, beliefs, understanding - that is meaning comes from anything but the interaction between subject and the object – one is imposing meaning on the object	**Subjectivism** Meaning is imposed on the object by the subject – i.e. from ones thoughts - beliefs
Critical Realism The world exists but making sense of it is a human attribute	The notion that truth, meaning and therefore information comes into existence through the our engagement with the realities in our world i.e actors, humans, structures etc.	**Constructionism** Therefore meaning is not discovered as in objectivism but is constructed through interaction and involvement in that world.

that is quantifiable through objectivist techniques is valid and trustworthy, hence appropriate methods for collecting and managing that information are valid. This, however, implies that information is tangible, visible and therefore quantifiable. This would immediately lead to conflicts with other Figure 3 definitions. Boland (1987), for example, argues that *information is not a resource to be stockpiled as one or more factor of production. It is meaning and can only be achieved through dialogue in a human community. Information is not a commodity. It is a skilled human accomplishment.* This description requires information and meaning to be constructed between interaction of both subject and object, this would imply an epistemological approach to knowledge but provides no direction as to the ontological view.

It is interesting to note that if one takes the notion of information to be a commodity as Barford (1997) suggests, it is then easy to appreciate and understand why so much investment in information technology in terms of time, money and effort has been made within the business world. If organisations accept the importance of information and view it as a resource it seems inevitable that information and knowledge are inextricably linked to technology. Unfortunately, this belief that technology can create and deliver the appropriate information when needed is based on a flawed epistemological approach.

Conclusions

The purpose of this chapter has been to raise and clarify the issues that are raised when the term information is employed. There would be no point in attempting to assert a 'proper' definition for the term; objections would immediately be raised based upon prior usage. And, as should be obvious, many distinct perspectives exist. Nonetheless, if the informing sciences' is to thrive, we need to develop a common understanding of the multiple perspectives and be sure to identify which we are adopting when we employ the term.

The issues that need to be resolved in order to achieve such an understanding are formidable. Among those presented in the chapter include:

- the numerous interpretations of the notion of information
- identifying two generic views of information i.e. as a product and as a process is an initial method of raising debate
- understanding and acknowledging that individual backgrounds and beliefs impact on this notion of information
- identifying that depending on an individual understanding of information will influence what is seen as valid and useful data

- investigating how information is created focuses on the epistemological aspect of information and therefore clarifies what is information in relation to the individual and the organisation
- where to focus training i.e. in terms of individual needs within the organisation, how and where to development individual skill is dependent upon the epistemological view of information
- data, information and knowledge are not separate entities there is a dynamic and circular interaction between them which places the human element at the centre. Individual knowledge can generate new data and this is a recurring process

The need to address the common ambiguities in our understanding of information is pressing. It is the very presence of a shared understanding that distinguishes that which is transdisciplinary from that which is merely multidisciplinary.

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Chapter 7

Task Complexity and Informing Science: A Synthesis

T. Grandon Gill and Richard C. Hicks

Introduction

The driving force behind the creation of informing environments and delivery systems is that a task needs to be accomplished. (Cohen, 1999)

The concept of a task is central to informing science (IS). As the driving force in the development of informing systems, the role played by task is of particular significance to the individuals responsible for developing such systems, since better insights into the task to be accomplished should improve their understanding of the resources that will be required. In this context, task complexity appears to be a particularly important characteristic. The construct is widely used in the behavioral sciences to explore the relationship between task characteristics and cognitive activities. It is hypothesized to be:

1. A determinant of the information processing and cognitive load that will be required in order to perform a task (Benbasat and Todd, 1996; Campbell, 1988).
2. An objective basis for determining compensation for a task (e.g., Auster, 1989).
3. A key determinant of task performer intrinsic motivation, satisfaction and goal acceptance (e.g., Jimmieson and Terry, 1999; Wood, Mento and Locke, 1987; Seybolt, 1976; Beer, 1968)
4. An important determinant of the general and specific knowledge required in order to perform a task (Wood, 1986)
5. An important determinant of appropriate training method for a given task (Bolt et al., 2001)

6. A critical factor in the selection of decision-making strategies and information seeking behaviors (e.g., Vakkari, 1999; Payne, 1976; March and Simon, 1958)
7. A variable impacting the appropriate method for displaying information in order to achieve effective decision-making (Speier and Morris, 2003)
8. A factor determining the value of data quality information in data warehousing situations (Fisher et al., 2003)

Given that the coming of the "information age" is being accompanied by a transition from physical work to "'knowledge work" (Drucker, 1989), and that discontinuous change (Handy, 1990) and high-velocity environments (Bourgeois and Eisenhardt, 1988) are leading to dramatic changes in the nature of tasks and jobs being performed, it is reasonable to anticipate that the potential value of being able to predict how abstract task characteristics will influence the intended task-completion system (Cohen, 1999) should grow correspondingly.

Given both task complexity's importance in the behavioral literature and its integral relationship to information processing activities, it is somewhat surprising that the construct has not been used more extensively in informing science. With few exceptions (e.g., Handzic, 2001), most of the research in the area has been situated in the field of management information systems (MIS). Even there, its use has been limited to a rapidly growing a number of studies that have used the construct as an independent variable (e.g., Mykytyn and Green, 1992; Barki et al., 1993; Jacko et al., 1996; Gill, 1996; Blili et al., 1998; Swink and Speier, 1999; Liao and Palvia, 2000; Mascha, 2001; Bolt et al., 2003; Fisher et al., 2003; Speier and Morris, 2003; Kishore et al., 2004; Roberts et al., 2004) in the prediction of some other outcome. There are also examples of research that employ MIS-related tasks as part of general investigations of the construct (e.g., Campbell and Gingrich, 1986). What is notably absent from the IS literature is a systematic examination of the nature of the construct. As the present chapter will demonstrate, such an examination is long overdue—as it is hard to imagine any other construct could equal task complexity in terms of the level of ambiguity and internal inconsistency achieved over the years.

Applying task complexity to IS situations has been made even more difficult by the way the construct has commonly come to be defined. Over the past two decades, the most widely used definition in the behavioral literature treats the construct as a function of objective task characteristics. Defined in this way, task complexity is most relevant to static, well-understood tasks (as will be explained later in the present chapter). Such a limitation of task domain, however, dramatically reduces the construct's potential applicability to the IS field. As IS researchers and practitioners, we routinely encounter situations where the tasks we consider are neither static nor fully understood. Three important examples are:

1. *Development of applications to perform tasks.* How does the complexity of a task impact the design, construction and implementation of information technologies appropriate for performing that task?
2. *Transformation of tasks by IT.* How does the complexity of a task change after it has been transformed through the adoption of an information system?
3. *Shared tasks.* How does the complexity of a task change when the performance of the task is shared between a human performer and an information system?

We believe that the question "how can task complexity be applied to IS?" is an important one. The present chapter proposes an organizing framework intended to clarify the applicability of task complexity to IS theory and practice. We begin by reviewing the many existing definitions of task complexity that have been proposed in the behavioral literature. In the course of doing so, we also draw parallels to analogous constructs that have been proposed in software engineering and the cognitive sciences. These definitions, thirteen in all, are then organized into a taxonomy consisting of five classes of task complexity that we have developed. Finally, we discuss the specific application of the complexity classes to a number of IS-related situations, and show how the interaction between different classes of task complexity can serve as a rich source of experimental hypotheses. We believe that this research can serve as an important first step in making the task complexity construct more applicable to IS research and practice.

Nature of a Task

Prior to addressing task complexity, it is useful to present definitions for three terms that are used throughout the present chapter: task, problem space, and discretion. All three prove to be critical in understanding the nature of task complexity.

Task

At least four distinct theoretical frameworks for studying tasks have been proposed (Hackman, 1969), treating tasks 1) in stimulus-response terms ("Task qua task"), 2) as a set of required behaviors, 3) as a set of resultant behaviors, and 4) as a set of abilities requirements (Wood, 1986). The present chapter does not make any judgments regarding the relative suitability of these different approaches to defining a task. Indeed, we believe consistent task complexity definitions can be established using any of the task conceptions, so long as they are not mixed. As a starting point, the present chapter adopts a definition of task that has been widely used in the past (Hackman, 1969):

> *Definition*: a task is a set of assigned a) goals to be achieved, b) instructions to be performed, or c) a mix of the two.

By defining task in this manner, we allow for tasks to be framed either in stimulus-response terms or as required behaviors, referred to as *prescribed activities*. We also specifically seek to separate task and task-context, the latter including broader factors such as the physical and social setting in which the task is performed. Later in the chapter, we return to this issue by considering how context factors, such as external demands on the task performer, can be expected to impact various conceptions of task complexity.

Problem Space

As already noted, abilities requirements are sometimes used as an alternative way of defining task. Such requirements are central to some task complexity definitions, but to avoid confusion we prefer to use another term to refer to them. Specifically, we adopt the term problem space (Newell and Simon, 1972), used extensively in the field of cognitive science. We define it as follows:

> *Definition:* A problem space is a representation of the cognitive system that will be used to perform a task "described in terms of (1) a set of states of knowledge, (2) operators for changing one state into another, (3) constraints on applying operators, and (4) control knowledge for deciding what knowledge to apply next" (Card, Moran and Newell, 1983; p. 87).

Within a problem space, knowledge is often classified in two forms: programs and meta-knowledge. Programs represent domain-specific knowledge that is normally the result of experience or training in the specific task to be performed, or very similar tasks. Meta-knowledge, in contrast, consists of knowledge about knowledge. It typically provides the task performer with access to a variety of search intensive, general problem solving strategies, such as reasoning by analogy (Rumelhart and Norman, 1981) and decomposition (Simon, 1981). These strategies (sometimes referred to as "weak methods"—so named because they offer no guarantees of success and are often quite inefficient) allow task performance to continue in the absence of programs.

Discretion

Under the definition of task that we have chosen, two assignments—1) serve cake for dessert, and 2) perform the steps in the recipe (for baking a chocolate cake) found on page 675 of The Joy of Cooking (Rombauer and Becker, 1975) commencing at 4:30 PM today—would both be valid tasks. To distinguish between the two tasks, it is useful to define a final term:

> *Definition:* the ability of a task performer to choose and/or sequence the activities associated with performing a given task is referred to as task discretion.

Using this definition, the first set of instructions (i.e., "serve cake for dessert") offers high levels of discretion, while the second offers nearly none.

Another way of viewing discretion is in terms of the set of acceptable problem spaces that are invoked by the task stimulus. For a low discretion task, relatively few problem spaces will meet the task requirements. For a high discretion task, on the other hand, many different problem spaces may exist that meet task requirements. As a result, rising discretion will typically be accompanied by a rise in the variety of task performance behaviors that are observed across different performers.

A Task Model

The relationship of task, problem space and discretion can be illustrated using a simple model, presented in Figure 1:

- For tasks with little or no discretion, the task stimulus invokes a specific problem space, which is then applied during task performance.
- For tasks with high discretion, the task stimulus invokes a collection of problem spaces that all meet, or may meet, task requirements. From that collection, a specific space is selected, which is then applied during task performance.

For some high-discretion tasks, weak methods may need to be employed because no invoked problem space offers an acceptable and fully determined path to task completion. In this case, a typical strategy is to use decomposition to break the task into subgoals, then perform each separately. This process adds an iterative component to task performance, illustrated by the dotted arrow in Figure 1. Such tasks are often referred to as ill-structured.

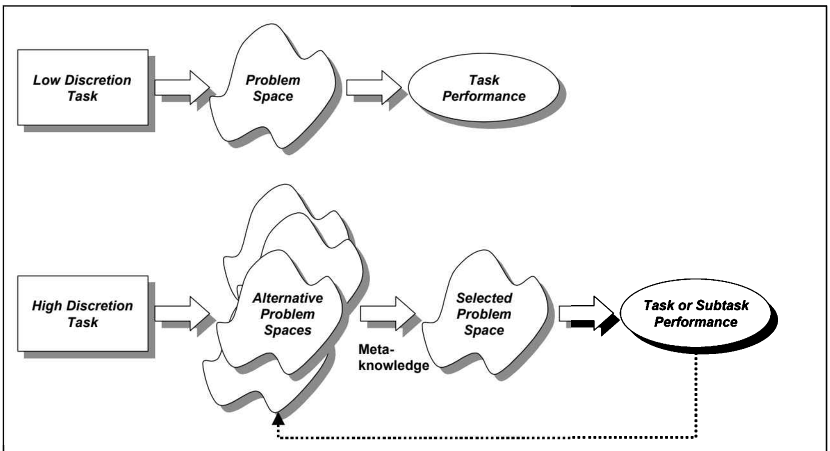

Figure 1: Relationship of Task, Problem Space and Discretion

Task Complexity: A Review

In this section, we review existing definitions of task complexity. We begin by discussing the most widely used class of definitions—objective complexity. We then present a broader survey of the construct as it has been applied in the behavioral literature.

Objective Complexity

Within the behavioral literature, two definitions of task complexity are most widely cited, those proposed by Wood (1986) and Campbell (1988). The first definition (Wood, 1986) is based on the premise that the only task complexity definitions likely to exhibit construct validity are those in which the construct is solely a function of the task itself. Referred to as objective task complexity, the definition proposes that task complexity derives from three primary sources: 1) the number of different components associated with the task (component complexity), 2) the level of interaction between the components (coordinative complexity) and 3) the degree to which the relationship between task-related input and output cues changes over time (dynamic complexity). Total task complexity is further proposed to be a weighted sum (or more complex function) of the three objective complexity sources.

The second definition (Campbell, 1988) similarly favors defining task complexity based upon objective task characteristics. The characteristics proposed are: 1) multiple paths, 2) multiple end states, 3) conflicting interdependence, and 4) uncertainty or probabilistic linkages. While the two definitions seem quite different, there is a strong underlying common theme:

> *Definition:* objective complexity defines task complexity as a function whose value depends strictly upon the characteristics of the task to be performed.

Unfortunately, objective complexity definitions have limited potential applicability to many common IT-related situations. Throughout the present chapter, we focus on three such situations:

1) the application of task complexity to systems development.
2) the application of task complexity to tasks transformed by IT, and
3) the application of task complexity to situations where task performance is shared between human performers and IT.

Relating these to the IS framework (Cohen, 1999), the first situation—systems development—can be characterized as an intent to change to the informing environment by creating a system using well understood designs or by creating a system of a totally new design. The relevant questions then become: what does the complexity of the task to be accomplished tell us about the changes we'll have to make to the informing environment and what are the implications for the delivery environment? The last two situations specifically relate to the nature of the task completion system. The relevant questions here become: what, if any, impact on task complexity occurs when IT is introduced to into a task completion system and can better understanding of task complexity provide us with useful insights into the nature of that system? We now consider the inherent limitations of objective complexity when applied to these situations.

Task Complexity and Systems Development

The development of information systems to perform a given task is an area that is at the heart of informing science, the creation of the delivery system (Cohen, 1999). It is also, arguably, the area in which objective task complexity (or concepts very similar to it) has been most extensively applied. Indeed, a typical system specification represents an almost ideal foundation from which objective complexity measures (e.g., number of functional components, component interdependence) can be estimated. Moreover, systems development has also been used as a domain for investigations into objective task complexity (Campbell and Gingrich, 1986).

The first issue that needs to be addressed in applying objective complexity to systems is determining the proper task domain. Two plausible alternatives exist: 1) we might want to estimate the complexity of the task of developing the system or 2) we might want to estimate the complexity of the task to be performed by the system. Given a full specification, a reasonable case can be made that measures of objective complexity computed on the basis of the specification represent the predicted complexity of the development task to be performed (Tran et al., 2004). This use of objective complexity comes with important limitations, however. The first limitation is that a full design specification must be in place. While specification will normally precede development in specification-based models, such as the waterfall model (Sommerville, 1996), many evolutionary development programming approaches, such as agile methods, permit major changes to design and specifications to merge incrementally during the development process. The second limitation is one of practicality: the value of being able to predict the complexity of the development process is much greater at the outset of the process than in the middle of the process.

Unfortunately, by the time a full set of specifications and design documents are completed and signed off in a typical waterfall model development project, developers are often nearing the midpoint of the project.

Even assuming a full specification is in place, there is little basis for treating that specification as a proxy for the objective complexity of the task to be performed by the system. For non-trivial systems, such specifications are rarely "determined" by the task itself. Instead, they evolve only as decisions regarding representation, approach and delivery platform are made. Thus, while it might be valid to measure the objective complexity *of the development task* implied by a particular system design, it would not be valid to assert that such complexity reflects the "objective" complexity of the *task to be performed by the system.* Referring back to Figure 1, systems development tends to be a high-discretion task where the process of moving from task to final problem space (i.e., full specification) is central to task performance.

Task Complexity and Tasks Transformed by IT

Objective complexity can also be very difficult to apply in situations where tasks are transformed by IT. A recurrent theme in MIS research is that IT is dramatically changing the way we work (e.g., Applegate et al., 1988). The ability to apply a task complexity construct to a continuous stream of new tasks would therefore be of particular value to the MIS field. In practice, however, the objective attributes that will ultimately prove to be relevant to a new task often need to be discovered (Jaikumar and Bohn, 1986). To measure objective complexity, however, these attributes need to be identified and understood. As a result, in a highly dynamic task environment, the objective complexity of new tasks is likely to be immeasurable during the precise period when the construct would be of the greatest value.

Task Complexity and Shared Tasks

Another serious limitation of objective complexity is evident when tools are used in performing a task. The voluntary adoption of an information system in performing a task —such as a decision support system (DSS)—would not impact the task's objective complexity, as a matter of definition. (The use of the term "voluntary" is important here, as a new requirement to use a tool represents a change to the task itself.) The problem that this creates is that use of a tool can dramatically impact many aspects of task performance that the presence of task complexity is supposed to predict (e.g., cognitive demands of the task; Campbell, 1988). Thus, availability of discretion in the use of tools can strip objective complexity of nearly all of its predictive power.

Alternative Task Complexity Definitions

Although objective complexity is often considered in the context of MIS-related tasks (e.g., Bolt, et al., 2001), limitations to its applicability—such as those just presented—significantly reduce its potential value in the IS field. Objective complexity, however, is only one form of task complexity present in the behavioral literature. We now turn to a more systematic review and synthesis of a broader range of complexity definitions, gathered according to the following procedure:

1. The task complexity research cited in earlier reviews (Wood, 1986; Campbell, 1988), either jointly or individually, was examined.
2. Usages of task complexity subsequent to the earlier reviews were identified using the ABI/Inform database, and a further gathering and analysis of included references was performed.
3. Selected references applying constructs related to task complexity in non-administrative disciplines (e.g., cognitive science, information theory, computer science) were identified as a means of broadening the present chapter's perspective.

Three distinct issues had to be addressed as part of the review: 1) research that did not specifically identify how the construct was defined, 2) research where the definition and the operationalization were inconsistent, and 3) research where multiple definitions were proposed. In the first case, a definition consistent with usage was assumed. In the second and third cases, each definition was cataloged separately. Upon completing this process, we were able to identify thirteen relatively distinct definitions of task complexity, summarized in Table 1.

Table 1: Existing Task Complexity Constructs

Construct Type	Description	Examples (References may fall in more than one category)
1. Degree of difficulty	Definition treats task complexity as a measure of the task's potential for being perceived as difficult by the task performer. May be operationalized based upon performer-reported assessments of difficulty, or upon indirect measures, such as the degree to which the task must be constantly attended to.	Huber (1985), Ursic & Helgeson (1990), Wofford et al. (1992), Blili et al. (1998), Nordqvist et al. (2004), O'Donnell et al. (2005)
2. Sum of JCI or JDS factors	Defines task complexity in terms of the task's potential to induce a state of arousal or enrichment in the task performer, operationalized using instruments such as the JCI (Job Characteristics Index) or JDS (Job Diagnostic Survey).	Schanke et al. (1984), Koslowski & Hults (1986), Specht (1986), Nordqvist et al. (2004)
3. Degree of stimulation	Definition treats task complexity as a measure of the task's potential to induce a state of stimulation or arousal in the task performer. Similar to degree of difficulty except that it is normally measured using physiological measurements (e.g., pupil dilation) as opposed to self-reporting.	Driver and Streufert (1966), Kreitler et al. (1974), Gardner (1990)

4. Amount of work required to complete the task or information load associated with the task	Definition treats task complexity as a measure of a task's potential to induce various information processing levels, such as peak processing rate (e.g., bits/second) or total amount of processing (e.g., bits processed). Such processing is intended to be measured objectively, instead of being based on task performer perceptions or responses. It is also nearly always constructed so that task performance strategy is held constant.	Barrow (1976), Seybolt (1976), Earley (1985), Campbell & Gingrich (1986), Gilliland & Landis (1992), Barki et al. (1993), Coll et al. (1994), Asare & McDaniel (1996), Benbasat & Todd (1996), Ho & Weigelt (1996), Schweizer (1996), Speier et al. (2003), Roberts et al. (2004)
5. Amount of knowledge	Definition is based upon the amount of knowledge that must be acquired in order to perform the task. Definition may be operationalized using metrics such as the amount of time required to learn the task.	Wood (1986), Ackerman (1992), Gill (1996)
6. Size	Defines task complexity using the information theory of the minimum theoretical size of the problem space necessary to perform the task. Most commonly used in assessing software complexity.	Li and Vitanyi (1993)
7. Number of paths	Defines task complexity in terms of the number of alternative paths that are possible using given performance strategy. Has been used for both general tasks and for analyzing the complexity of computer programs, where it measures the number of branches (e.g., if constructs).	McCabe (1976), Campbell (1988), Barki et al. (1993), Jacko & Salvendy (1996)

8. Degree of task structure	Defines task complexity as the degree to which a task is not programmed, i.e., the degree to which accepted task-specific procedures for performing the task do not exist. Lack of structure can result from a number of sources, including the lack of a clear goal state to be achieved, the inability to establish the initial starting point of the task and relevant task attributes, and/or a lack of knowledge of strategies suitable for moving between the initial state and the goal state.	Zemelman et al. (1985), Lengnick-Hall et al. (1985), Bronner (1986), Collins & Hull (1986), Abdolmohammadi & Wright (1987), Smith (1988), Gilliland & Landis (1992), Barki et al. (1993), Bystrom & Jarvelin (1995), Vakkari (1998,1999), Jimmieson & Terry (1999), Mascha (2001), Nordqvist et al. (2004), Sheer & Chen (2004)
9. Non-routineness or novelty of task	Defines task complexity in terms of the degree to which the task is unfamiliar to the task performer. A routine task is typically viewed as the opposite of a complex task under this definition.	Beer (1968), Frew (1981), Jiambalvo & Pratt (1982), Wagner & Gooding (1987), Jehn et al. (1999), Jimmieson & Terry (1999), Schwartzwald et al. (2004)
10. Degree of uncertainty	Defines task complexity as the degree to which actual performance of the task cannot be predicted at the outset of the task owing to uncertainty. Normally, such uncertainty can arise as a result of lack of structure (see above) or from stochastic uncertainties inherent in the task itself.	Belardo & Pazer (1985),Wagner & Gooding (1987), Taylor (1987), Te'eni (1989), Barki, *et al.* (1993), Kishore, *et al.* (2004)
11. Complexity of underlying system or environment	Definition specifically relates to the task of controlling or predicting the behavior of systems. Defines task complexity in terms of the objective attributes of the system (e.g., number of components, degree of interrelationships).	Culnan (1983), Kottlemann & Remus (1989), Funke (1991), Dorner & Scholkopf (1991)

12. Function of alternatives and attributes	Specifically focused on choice tasks, definition treats task complexity to be an objective function of the alternatives available in the task (e.g., number of alternatives, discriminability) and the task's attributes (e.g., the number of criteria needing to be considered, the degree to which they are interdependent).	Pollay (1970), Payne (1976), Lussier and Olshavsky (1979), Olshavsky (1979), Javalgi (1988), Paquette & Kida (1988), Swink & Speier (1999), Fisher et al. (2003), Klemz & Gruca (2003).
13. Function of task characteristics	A more general version of the attributes-alternatives definition of task complexity, it defines task complexity to be direct function of all possible task characteristics, such as inherent uncertainties in the nature of the task, tradeoffs that must be made between different goal criteria, and the degree to which steps taken in performing the task are irreversible.	Belardo & Pazer (1985), Earley (1985), Wood (1986), Wood et al. (1987), Campbell (1988), Auster (1989), Wood et al. (1990), Chesney & Locke (1991), Mykytyn and Green (1992), Weingart (1992), Fisher (1993), Argote et al. (1995), Korsgaard & Diddams (1996), Jones et al. (1997), Liao & Palvia (2000), Bolt et al. (2001), Klein et al.(2001), Speier & Morris (2003), Speier et al. (2003), Roberts et al. (2004), Tran et al. (2004),White & Lui (2005)

In organizing these thirteen definitions, we initially attempted to group them into three previously proposed perspectives (Campbell, 1988). These perspectives are:

1. The psychological experience perspective, defining task complexity in terms of its impact on task performers (e.g., perceived difficulty).
2. The task-person interaction perspective, defining task complexity as a construct that can only be determined when both the task and the individual performing the task are taken into account.

3. The objective characteristics perspective, defining task complexity in a manner consistent with objective complexity, as previously discussed.

A number of definitions we identified fell readily into the first group. In three of these definitions, task complexity was defined to be the underlying source of some observable performer-experienced outcome, such as performer-perceived difficulty (definition 1), enrichment (definition 2), and arousal (definition 3). A fourth definition, information processing (IP) activity (definition 4), was similar except that the outcome—IP activity—could be extended to non-human performers (e.g., processing cycles, bits processed).

At the other extreme, there was a cluster of objective complexity definitions (i.e., definitions 11-13). While the specific task attributes viewed as relevant varied considerably across these definitions, all viewed the complexity of the task to be independent of performer and task-context issues that were not part of the task itself.

The middle group of definitions proved to be the most difficult to classify. With the psychological experience group, they shared a tendency to define task complexity in terms of variables that were, at least in part, likely to be a function of the performer rather than the specific task (e.g., amount of knowledge, task structure, routineness). On the other hand, similar to the objective characteristics group, they treated task complexity as an observable variable in its own right, and not merely as the underlying source of some measurable task-related outcome.

Our analysis of these definitions suggested that a number of problems arise from lumping them together in a single, catchall person-task perspective. For example, many of the definitions within the group were only weakly related to each other, such as the novelty of a task (definition 9) and the number of paths available for task performance (definition 7). In addition, the use of the term “person” in "person-task" appeared unduly restrictive, especially if we are interested in person-IT pairings. Furthermore, a number of useful ways of thinking about task complexity have been developed in the field of computer science (e.g., Kolmogorov complexity, Li and Vitanyi, 1993; cyclomatic complexity, McCabe, 1976), where the task performer is not a person. Finally, some of the definitions could move between perspective categories depending upon how a task is presented. For example, where a task consists solely of prescribed activities (i.e., programs), both uncertainty (definition 10) and number of paths (definition 7) are likely to be objective characteristics of the task itself (Campbell, 1988). On the other hand, where a task is presented purely in terms of goals, and discretion is present, these same definitions can be highly dependent upon the problem space utilized by the task performer. For example, if we have two task experts who choose to perform a given task in different ways, can we really state that the number of paths experienced by each expert is an objective attribute of the task itself?

The middle group of definitions also proves to be particularly important because many involve concepts that have demonstrated relevance to MIS development and implementation. For example:

- Size (definition 6), lack of structure (definition 8) and inexperience with technology (definition 9) have been found to be the primary sources of development risk in large IT projects (Cash, et al., 1988),
- Number of paths (definition 7) per unit of software has been found to be a predictor of software defects (e.g., Gill and Kemerer, 1991).
- Lack of structure (definition 8) has been identified as an important task characteristic in choosing between types of IT (e.g., conventional system, DSS and expert system; Luconi, et al., 1986).

To derive an internally consistent classification, we extended the three original perspectives into five classes of complexity definitions that, taken together, seemed to encompass all widely used definitions that we identified in the literature.

Five Classes of Task Complexity

In rethinking the three task complexity perspectives, we found that existing definitions could be organized using two dimensions: performer dependence and area of focus.

Performer Dependence

The performer dependence dimension deals with the question of whether or not the defined complexity of a task necessarily depends on the nature of the performer. Five of the Table 1 definitions are inherently performer dependent. The first three of these—(1) degree of difficulty, (2) sum of JCI or JDS factors, (3) degree of stimulation—are strongly influenced by a broad range of non-task factors, including attitudes and personal capabilities. Two additional definitions—(8) degree of task structure, and (9) non-routineness or novelty of task—are likely to be influenced both by experience performing the task and by the meta-knowledge that the performer has accumulated since birth. One could, in theory, overcome these dependencies by applying these constructs only to low-discretion, practiced tasks—both eliminating the need for meta-knowledge and controlling for experience. Doing so would be pointless, however, since it would guarantee that the resulting tasks would be characterized as both structured and routine—making them "low complexity" by definition.

Seven definitions, in contrast, are specifically constructed so that they are not necessarily performer dependent. One of these definitions—(4) amount of work required to complete the task or information load associated with the task using specific strategy—is nearly always applied in situations where task performance strategy is controlled (i.e., it is measured for a particular problem space). Three of the definitions—(5) amount of knowledge, (6) size, (7) number of paths—are metrics of a specific problem space, which could (at least in theory) be employed by different performers. The last three definitions—(11) complexity of underlying system or environment, (12) function of alternatives and attributes, and (13) function of task characteristics—are forms of objective complexity, specifically limited to task attributes.

Only one definition, degree of uncertainty (10), cannot readily be classified along the performer dependence dimension. The problem here is the ambiguity in its usage present in the literature. Sometimes, "uncertainty" is used to describe the inability to identify the most appropriate available strategy during performance of the task owing to lack of task performer knowledge. In such cases, uncertainty can be classified as performer dependent, and is closely related to lack of structure. On other occasions, however, the term is used to describe probabilistic linkages inherent in the task (e.g., Campbell, 1988), such as outcomes in a game that depend upon the roll of a die. In such cases, uncertainty is performer independent.

Area of Focus

The second dimension used in classifying complexity definitions is area of focus. Task complexity definitions generally emphasize one or more of three areas: 1) task complexity as the underlying source of some measurable outcome during task performance (e.g., information processing activity), 2) task complexity as a descriptor of the characteristics of the internal process to be used to perform the task (e.g., the problem space) and 3) task complexity as a function of some collection of inputs that are determined by the task itself (e.g., number of attributes and alternatives).

Of the thirteen definitions, four fall into the outcome category: (1) degree of difficulty, (2) sum of JCI or JDS factors, (3) degree of stimulation, and (4) amount of work required to complete the task or information load associated with the task. In these definitions, presence of the specified outcome is de facto proof that task complexity is present. Another three fall into the internal process category: (5) amount of knowledge, (6) size, and (7) number of paths. In these definitions, task complexity cannot be determined without knowing quantitative and/or qualitative information regarding how the task is to be performed. Three of the remaining definitions define complexity as a function of inputs that are strictly determined by the task itself: (11) complexity of underlying system or environment, (12) function of alternatives and attributes, and (13) function of task characteristics.

A final set of definitions, (8) degree of task structure, (9) non-routineness or novelty of task, and (10) task uncertainty, are best described as constructs that depend on the interaction between the inputs and internal problem space areas of focus. For example, a given task may have some cases (i.e., combinations of inputs) that are routine and some that are novel for a given performer. The degree of structure present in a task, and associated levels of uncertainty associated with task performance, can also be sensitive to inputs. A good example of this, drawn from the MIS area, is the problem of scalability, occurring where a well-defined approach to a task involving a small number of inputs (e.g., low objective complexity) ceases to be effective for larger versions of the same task. In artificial intelligence, the frequent failure of "toy problem" systems to grow into practical intelligent systems is well documented (Dreyfus, 1981).

Five Task Complexity Classes

The thirteen complexity definitions, organized according to the performer dependence and area of focus dimensions, are presented in Table 2.

Table 2: Definitions Organized by Performer Dependence and Area of Focus

		Area of Focus		
		Outcomes	Internal	Inputs
Performer Dependence	Dependent	*1. Degree of difficulty* *2. Sum of JCI or JDS factors* *3. Degree of stimulation*	*8. Degree of task structure* *9. Non-routineness or novelty of task* *10. Degree of uncertainty (present during task performance)*	
	Independent	*4. Amount of work required to complete the task or information load associated with the task (using a specified strategy).*	*5. Amount of knowledge* *6. Size* *7. Number of paths*	*10. Degree of uncertainty (inherent to task)* *11. Complexity of underlying system or environment* *12. Function of alternatives and attributes* *13. Function of task characteristics*

This presentation, in turn, suggests the existence of 5 distinct classes of task complexity definitions, as shown in Table 3.

Table 3: Task Complexity Classes

Name	Form of Definition	Description/Example
Experienced	**Task Complexity → Psychological state**	If an individual perceives a task to be difficult, then the task is complex
Information Processing	**Task Complexity → IP Activity**	If a task a task produces high information processing, then the task is complex
Problem Space	**Problem Space Attributes → Task Complexity**	*Example*: A task's complexity is defined by the minimum size of the computer program required to perform the task.
Structure	**Lack of Structure → Task Complexity**	*Example:* The more routine a task, the less complex it is
Objective	**Task Characteristics → Task Complexity**	*Example:* A task's complexity is determined by the number of task elements, the degree of interrelationship between the elements and the degree to which task objectives are changing (Wood, 1986).

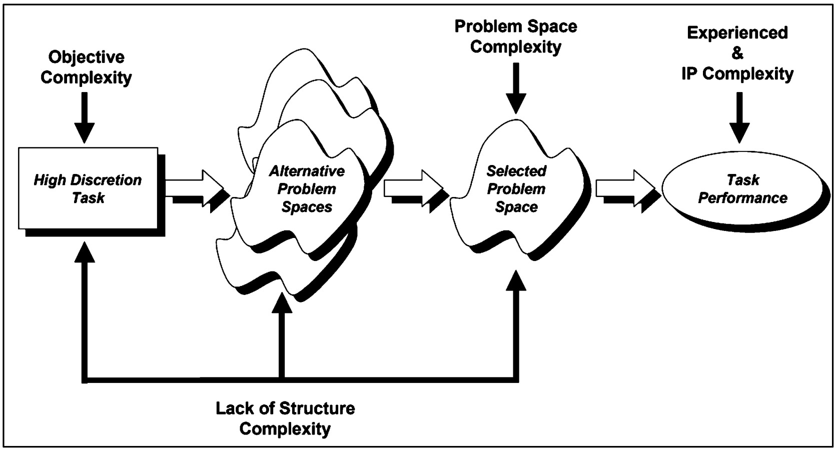

Figure 2: Complexity Classes and Area of Focus

The area of focus for each of the five classes of complexity, presented in the context of our task model, is illustrated in Figure 2.

Discussion

In this section, we consider how the comprehensive task complexity classes might be applied to the three areas of specific interest to IS that were previously identified, i.e., systems development, task transformation and task sharing. In these discussions, potential areas for future research are also identified.

Task Complexity and Task Transformation

A task complexity construct that cannot accommodate changing tasks will be of severely limited value in a dynamic task environment. In such an environment, insights into novel and evolving tasks are likely to be far more useful than the ability to measure the complexity of static, routine tasks. Accepting the widely acknowledged potential of IT to transform work as a given, it follows that task complexity's ability to address transformation issues such as learning and changing task performers will significantly impact its potential value the IS community.

The five complexity classes can be expected to exhibit very different behaviors in a dynamic task environment. These behaviors are of interest for two reasons. First, they provide insights into how task complexity can be applied and interpreted. Second, the expected interaction between task complexity classes can serve as a basis of hypotheses suitable for future research. In this section, we consider how task complexity is impacted by changes within the task performer (e.g., learning, practice) and to the task performer (e.g., enabling new individuals to perform a task).

Task Complexity and Learning

In theoretical terms, learning can be treated as changes to the task performer's problem space. Such changes occur in a number of ways (Rumelhart and Norman, 1981), ranging from incremental improvements in performance (e.g., accretion) to complete transformation of knowledge (e.g., restructuring).

To understand how the classes of complexity vary as the problem space changes, we need to view these changes in the context of a theoretical model of knowledge acquisition. A fairly common theme—among the many models that exist—treats knowledge acquisition as a series of three loosely defined stages (Ackerman, 1992):

- *Cognitive:* Very little immediate knowledge is present, therefore the bulk of task performance relies on search. Because such search will often involve techniques that access knowledge outside of the task domain (e.g., reasoning by analogy), the potential size of the problem space is: a) likely to be very large as it is effectively unbounded by the demands of the task, and b) likely to differ dramatically across performers. Because search is very processing intensive, information processing will also tend to be high.
- *Associative:* With growing expertise, task-specific knowledge is substituted for search and less information is therefore required (Camerer and Johnson, 1991). As a consequence, the problem space becomes bounded and actually shrinks, meaning that problem space complexity declines. Similarly, IP requirements tend to shrink as efficiency improves.
- *Autonomous:* As the expert grows more advanced, additional knowledge about the task continues to be learned, leading to a gradual increase in size for the problem space and the associated problem space class of complexity. The knowledge versus search tradeoff implies that while problem space complexity continues to grow, other classes of complexity (e.g., IP complexity, experienced complexity) are likely to level off, or decline.

Progressing through these stages of knowledge acquisition, we would therefore expect to see the following changes in the task complexity classes, illustrated in Figure 3:

- Psychological experience (definitions 1-3) and information processing (definition 4) measures should decline monotonically, as our efficiency in performing the task increases.
- Problem space complexity measures (definitions 5-7) first decline dramatically—as general knowledge is supplanted by task-specific knowledge and more compact problem spaces can be formed. A subsequent gradual decline in problem space size

may then occur as knowledge representation becomes more efficient, through schema tuning (Rumelhart and Norman, 1981). Finally, the problem space size begins to rise gradually through accretion. Interestingly enough, the pattern of tuning followed by accretion is also reported in the development of expert systems (e.g., Bachant and McDermott, 1984).

- Task structure (definitions 8-10) would continually increase, implying a decline in lack of structure complexity (mirroring that of experienced complexity).
- Objective characteristics measures (definitions 11-13) should remain unchanged throughout the learning process for a given task.

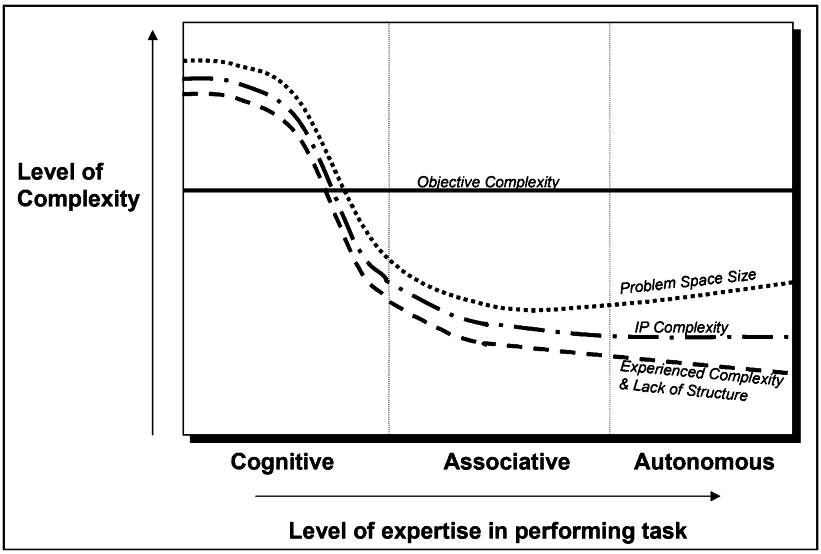

Figure 3: Typical Acquisition of Expertise Model

The hypothesized unchanging nature of objective complexity as knowledge is acquired has important implications for its appropriate use. For simple, static task situations—the type most commonly investigated in the behavioral literature—we have already noted that the presence of objective complexity is hypothesized to be a predictor of other forms of complexity, such as information processing (Campbell, 1988) or amount of task knowledge (Wood, 1986). In dynamic task settings, such as those common in IT environments, objective complexity measures are unlikely to be useful for this purpose. On the other hand, objective complexity may prove to be very useful for measuring system capabilities or predicting strategy changes. For example, during the development of R1 (later named XCON) there was a long-term accretion of rules that corresponded to an increase in the number of system types that R1 could be applied to (e.g., Bachant and McDermott,1984). In other words, increasing problem space size was accompanied by increased objective complexity capacity. With respect to task-performer experienced complexity, increasing objective complexity can act as a trigger for changes in task performance strategy that reduce cognitive demands (e.g., Payne, 1976; Payne, Bettman and Johnson, 1993).

Before leaving the subject of learning and task complexity altogether, it is useful to add a comment on the effects of practice on task complexity. As noted earlier, research into the acquisition of expertise (e.g., Shiffrin and Dumais, 1981) has shown that repeated performance of a task leads to automatism, whereby the task's demands on the task performer's cognitive resources will decline significantly. As a consequence, even where task performance strategy is controlled, we would expect psychological experience measures of task complexity (i.e., definitions 1-3) to decline with practice. Assuming, however, that all aspects of task performance are kept constant (e.g., task performance activities are prescribed or the performer problem space does not change), it would be expected that task complexity would not change according to the remaining measures. For example, once a concert performer learns a piano piece well enough to play it from memory, there would be no reason to assume that the complexity of the task of playing the piece declines with further practice—except from the perspective of the performer, who finds that it can be played with less and less conscious attention. Unlike other forms of learning, such practice effects can occur even when the overall structure of the problem space is unchanged.

Task Complexity and Alternative Performers

There are relatively few "real world" tasks where the entire domain of interest is limited to how the task is performed by a particular individual performer. When IT is introduced, the situation often becomes even more convoluted—as such technologies can enable task performance by new individuals (e.g., Gill, 1996). As a consequence, the question of how task complexity is affected by the presence of alternative or multiple performers is highly relevant to IS researchers and practitioners. Conceptually, there are a number of differences that can be present across performers, including:

- *Problem Space:* Different task performers may employ substantially different problem spaces.
- *Practice*: Even where performers employ essentially equivalent problem spaces, practice effects (already discussed) can lead to widely differing cognitive demands
- *Discretion:* Where task discretion is present, even with roughly similar experience levels, choices of individual strategies employed may vary based upon factors not intrinsic to the task, such as accumulated meta-knowledge.

As a result of these differences, task complexity can vary considerably across performers under many of the definitions.

The widest variation in complexity across performers is likely to be for the psychological experience and lack of structure classes (definitions 1-3 and 8-10). For this class, differences in task complexity can be the result of practice, problem space and discretion variations. For the information processing class (definition 4), the practice effect drops out. For the problem space (definitions 5-7) class, only variations in the problem space lead to differences in defined complexity. Finally, for the objective characteristics class (definitions 11-13), we would expect no differences in task complexity across performers.

Task Complexity and External Tools

Understanding how the use of tools, particularly IT-based tools, impact informing systems is a core question of informing science. Thus, the relationship between tools and task complexity (in its various forms) is central to the discipline. As was the case for alternative performers, the complexity classes differ widely in response to the introduction of tools.

The first issue that must be addressed relating to the use of tools is whether or not a tool is required. The requirement that a tool be employed represents a change in the nature of the task itself. Thus, we would anticipate that changing a task so that use of a tool is required would lead to changes in all the complexity classes.

Where the use of a tool (e.g., a software application) is discretionary, the expected impact on the task complexity classes is much less straightforward. For objective complexity (definitions 11-13), there should be no impact because use of the tool is not specified by the task. As a consequence (similar to what was seen in the case of learning) objective complexity is likely to be of limited use in predicting other complexity measures, such as IP, when tools are available but not required. Also similar to the learning situation, however, objective complexity may prove to be valuable in other contexts—such as estimating the "capacity" of the tool-performer combination or identifying threshold levels for tool use.

For psychological experience (definitions 1-3) and information processing (definition 4) complexity, at the other extreme, we can reasonably suppose that the most common result of voluntary use of an external tool use would be a decline in complexity measures experienced by the human task performer (particularly once the period of learning the tool has passed). It must be emphasized, however, that this expectation applies only to a given task case. Where a task performer must perform a stream of task cases, the technology-performer pairing can impact the mix of task cases performed. An example of such a task-mix change can be found in the case of the Authorizer's Assistant expert system, used to authorize American Express card charges (Gill, 1996). The system reduced the IP requirements associated with any given authorization (e.g., by accessing appropriate databases on different computers and presenting them in a single organized summary to the human authorizer, along with an accept/deny recommendation). However, the system also intercepted most routine approvals and handled them automatically, without user involvement. As a consequence, the task cases that actually reached the human authorizer were, on average, more challenging than the cases that they had previously approved manually.

For problem space (definitions 5-7) and lack of structure (definitions 8-10) complexity, the introduction of a tool can impact task complexity in either direction. On the one hand, the need to learn to use the tool could actually increase the size of the required problem space and could, at least temporarily, reduce task structure. The introduction of word processing technology, for example, probably increased the amount of knowledge required to be an effective typist. On the other hand, where a tool contains embedded expertise (e.g., an expert system), the availability of the tool could reduce the amount of knowledge required to perform a task, and make the task more structured. The introduction of search engines, as another example, dramatically reduced the amount of knowledge required to conduct an effective search of the Internet. In the adoption of expert systems, both increasing and decreasing knowledge requirements resulting from system adoption have been observed (Gill, 1996).

Task Complexity and the Fitness Landscape

A common theme throughout this chapter has been the inherent weakness of objective complexity, the most widely used definition of task complexity, for predicting other aspects of task performance, such as information processing and perceived usefulness. The problem only arises for high discretion tasks, of course. But most "interesting" tasks provide such discretion.

The fact that objective complexity cannot be used to predict IP-related outcomes reliably does not mean that it is not useful, however. To the contrary, the task characteristics that comprise objective complexity according to Wood (1986)—namely number or elements, interaction between elements, and dynamically changing goals—are precisely those that lead to fitness landscape ruggedness in evolutionary biology.

Because such ruggedness is the subject of Chapter 12 of this book, we will not address them at length here. In essence, a rugged fitness landscape is one where interactions between attributes (e.g., task characteristics) necessarily produce multiple combinations where fitness (e.g., quality of task performance) is maximized locally. According to the widely used N-K model (Kauffman, 1993), the number of peaks will be determined by the number of elements (N) and the degree to which these elements interact with each other (K, where K=0 implies no interaction and K=N-1 implies that the fitness function is, effectively, random or chaotic). The location of the peaks—corresponding to goals in a model focused on improving task performance—will, in turn, be impacted by interactions with co-evolving systems.

The expected impact of ruggedness on task performance would be to cause performers to gravitate to alternative approaches to the task that may be very different—much the way species evolve to their individual niches in an ecosystem. The further implication of this diversity in task performance would be to dramatically limit the degree to which observations of a particular task case or task performer can be expected to generalize to other cases and performers. How this can affect our research strategies is covered in considerable detail in Chapter 12, and further revisited in Chapter 22.

Conclusions

The underlying premise of the present chapter is that an understanding of task complexity could offer major benefits within informing science. Unlike some earlier papers on the subject of task complexity, however, we take no position regarding the "correct" definition of the construct. Far too many definitions have been proposed and used to allow us to define it by fiat. Instead, we have directed our attention to establishing five distinct ways that the construct can be consistently and rigorously defined, based on its usage in the literature: 1) as a psychological experience, 2) as a source of information processing potential, 3) as a characteristic of a problem space, 4) as measure of task structure and 5) as a function of task characteristics. We believe this analysis provides a useful point of departure for both researchers interested in applying the constructs and for practitioners seeking to interpret the findings of such research.

We have also drawn a number of conclusions regarding the use the construct within the IS area, including:

- Many IS situations are not well served by limiting task complexity to the "objective complexity" construct that is most commonly applied in the behavioral sciences.
- The potential relevance of different complexity classes may change during the stages of systems development, and may also be strongly impacted by the development approach taken.
- Understanding the behavior of the complexity classes in the presence of learning and human-computer task sharing is of particular interest to IS, since all three elements of the informing science framework (Cohen, 1999) come into play: the informing environment, the delivery system and the task-completion system. Considering the interrelationships between

the five complexity classes can enhance such understanding, and lead to many useful research questions.

We believe the task complexity classes that we have presented can serve as a useful tool for interpreting past research into task complexity. More importantly, we believe them to be a useful guide for future research that investigates or applies the construct. Such research is likely to be crucial as the scope of the tasks we automate increases, and the way we develop them becomes increasingly adaptive in nature.

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Chapter 8

Utility and Informing

T. Grandon Gill

Introduction

The notion of a utility function, that is to say a function that captures human preferences and thereby explains human choices, is fundamental to many business-related disciplines. In economics, it plays a foundational role in the mathematical derivation of general equilibrium theory and often plays a role in macroeconomic policy models. In the decision sciences, it is central to rational decision models involving risk and time. In management and finance, it serves as an important underpinning to a wide range of models, such as those employed in agency theory and prospect theory.

Within the informing sciences, the concept of utility is no less important. In Cohen's (1999) sender-channel-client model, the concept of utility is central to understanding why a sender chooses to inform and why a client chooses to be informed. In this context, utility can manifest itself in a number of ways. From an economic perspective, the value of being informed can be described as the marginal value of information for the task associated with the informing system. The greater the value of the information, the greater the contribution informing makes to the client's utility. Informing relationships may also exist, however, in contexts where marginal values cannot be calculated, or where they are irrelevant. Learning is often intrinsically motivated; we experience utility gains through the process of being informed, yet there is not necessarily an economic source that we can pinpoint to explain that utility. Neoclassical economic theory allows utility to include less tangible elements, such as personal sense of mastery, power, or the satisfaction of others (Simon, 1992). Incorporating such elements, however, makes the utility construct substantially less tractable for the purposes of generating formal economic theory.

Neoclassical economic utility has two largely unresolved aspects that make its use particularly problematic in the informing context. Even in its simplest form, a single variable and one time period, numerous departures from apparently rational behavior as predicted by neoclassical utility functions have been observed in experimental settings. Henceforth, we refer to these as anomalies. Many of these anomalies (e.g., framing, priming) represent behaviors where subtle aspects of how a decision task is presented—not affecting the underlying decision itself—result in changes to observed client preferences. Obviously, better understanding how such anomalies arise is critical if effective informing is to take place, since the presentation of task information is an integral part of most informing systems.

Even more troubling, from an informing perspective, is the degree to which learning is ignored in economic models of utility. Utility is presumed to guide our choices, yet we also know that our preferences may evolve as we gain expertise in a particular activity. Economists do posit a roll for changing tastes—although some (e.g., Becker, 1976) do their best to propose functions constructed so as to minimize the impact of such changes—but when our utility preferences change (e.g., as we gain expertise in performing a particular type of financial task), it is not convincing to assert that this change is solely a consequence of our changing taste for money. Even more to the point, how plausible is it to assume that preferences do not change as a consequence of the learning that invariably takes place over the course of an informing relationship?

The purpose of the present chapter is to synthesize existing research into an alternative formulation of the utility function that may serve to address some of the anomalies and inconsistencies common to many existing utility functions, particularly in the informing context. The chapter begins by summarizing existing models of utility and then reviews key findings of the goal-setting literature. It then formulates a utility model driven by individual goals, which is then expanded to incorporate learning. Finally, the chapter considers how predictions of the goal-based model might differ from existing models and the implications of these differences for the informing sciences.

Utility Theory

Utility generally refers to an individual state that combines notions of satisfaction, usefulness, and rationality. In economics, utility is often presented as a function of various goods and services $(x_1,x_2,\ldots,x_n)$ consumed in a period along with resources saved $(s_1,s_2,\ldots,s_n)$, e.g.,

$U(x_1,x_2,\ldots,x_n, s_1,s_2,\ldots,s_n)$

Neoclassical economic theory is built upon the assumption that any rational economic agent can be modeled as a utility maximizer. Conceptually, we may view the utility maximization process as a choice process wherein a decision-maker starts with a set of saved resources supplemented by earnings, considers how those resources may change as a consequence of possible actions available to him or her, and then selects that action leading to the highest expected utility outcome (where the outcome of an action may be a set of possible outcomes where uncertainty is present). We represent this model in Figure 1.

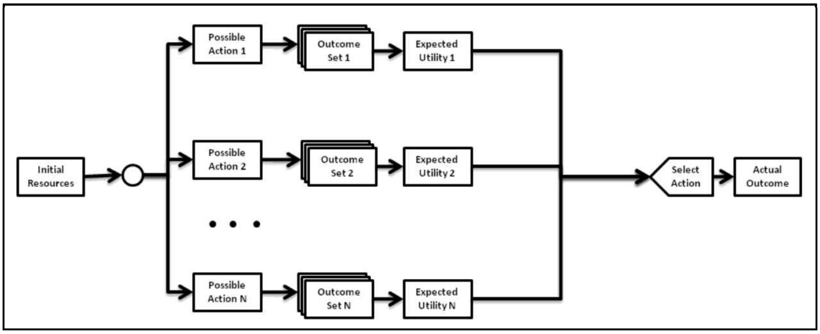

Figure 1: Classic Utility Model

The power of such a model in economic theory is undisputable. For example, using utility maximization as an axiom (combined with various assumptions regarding production functions) it becomes possible to demonstrate that a consistent set of demand and price values exist such that the result is general economic equilibrium (Allen, 1959). It is also possible to extend the model. For example, although not normally included in equilibrium models, it has been proposed that the independent values in the utility function (i.e., $x_1,x_2,\ldots,x_n$) need not be limited to goods and services but may also include less tangible elements such as power or the satisfaction of others (Simon, 1992). The idea of more abstract elements is also central to the notion of commodities in Becker's influential formulation of the household production function (Becker, 1976, p. 134). In addition, it has been widely recognized that human processing has significant limits and that available information is far less than the "perfect information" assumed in classical models. This recognition leads to a notion of bounded rationality (Simon, 1976) whereby a rational decision-maker limits utility maximizing activities once one or more satisfactory outcomes have been identified.

Because utility maximization is axiomatic to theories that postulate rational decision making, the underlying shape of individual utility functions has been researched extensively. Such research generally falls into one (or more) overlapping categories: the impact of risk on utility, the impact of time on utility, and the behavior of multi-attribute utility functions. Research into risk has focused on better understanding how people trade off costs and payoffs that include an element of randomness, either quantified (risk) or unspecified (uncertainty or ambiguity). The underlying theory involves a series of axioms (e.g., if outcome A is preferred to outcome B, then a gamble offering the probability of p for receiving A, 0 otherwise should always be preferred to a gamble with probability p of receiving B, 0 otherwise) that collectively define rational behavior under risk and ambiguity. In such choice situations, expected utility also becomes more critical than actual utility, as it is the former that is available prior to making the choice. One surprising result of this research has been the discovery of numerous anomalies that appear to call into question the rationality of actual human behavior (see Table 1).

A similar stream of research has examined utility tradeoffs over time, both with and without the presence of uncertainty. Corresponding axioms of rational behavior have been derived in the case of time (e.g., if payout A at t_0 is preferred to payout B at t_1, then payout A at t_n should be preferred to payout B at t_{n+1}). As was the case for risk and uncertainty, many temporal anomalies have also been identified (see Table 1). Hyperbolic discounting (Ainslie, 2001), which discounts short-term delays far more drastically than the more economically elegant exponential discounting, has been proposed as an explanation for a number of these.

Table 1: Anomalies in utility models of rational decision making

Anomaly	Description	Example Reference
	Preference Anomalies	
Framing effects	Individuals often express strong preferences when making choices between alternatives that are, in fact, identical.	Bell, Raiffa, & Tversky, 1988, p. 11.
Endowment effect	Upon acquiring an object, we value it far more than we did prior to acquiring it, leading to asymmetry between buying and selling prices.	Ariely, 2008, p. 130.
Anchoring	When establishing preferences, we typically anchor them to an available reference, even when that reference makes no sense (e.g., the last digits of a social security number).	Ariely, 2008, p. 28.
Preference reversal	When presented with two lotteries, individuals may prefer the less risky one yet be willing to pay more to participate in the riskier one.	Grether & Plott, 1979
Illusion of control	Individuals perceive that they exert far more control over random events than they actually do.	Langer, 1975, p. 231.
Cash effect	Experimental subjects react differently to cash rewards than to rewards easily convertible to cash.	Ariely, 2008, p. 220.
Availability bias	Judgments of likelihood are unduly influenced by the individual's ability to recall specific examples, which may or may not be representative.	Tversky & Kahneman, 1973, p. 163.
Expected value insensitivity	When presented choices of certainty and near certainty, we tend to prefer certainty even where payoff differences are substantial. As probabilities get very low, we focus on size of the payoff rather than its expected value.	Kahneman & Tversky, 1979, p. 267.

Temporal Anomalies		
Common difference	Identical payoffs separated by a fixed time period may change preference depending upon when the payoff is started. For example, you may prefer \$3000 now to \$4000 in a year, but also prefer \$4000 in year 4 to \$3000 in year 3.	Lowenstein & Prelec, 1992, p. 120.
Absolute magnitude effect	Ratios of preferences may change as payoffs change. For example, an individual may prefer \$15 now to \$60 in a year, but prefer \$4000 in a year to \$3000 now.	Lowenstein & Prelec, 1992, p. 121.
Gain-loss asymmetry	Losses are discounted at a greater rate than gains. For example, a study found an individual be indifferent to a gain of \$10 now to \$21 in a year, but be indifferent to a loss of \$10 now and a loss of \$15 in a year.	Lowenstein & Prelec, 1992, p. 122.
Delay-speedup asymmetry	Significant variations were found with respect to an individual's willingness to speed up consumption and delay consumption. In other words, they had to be paid more to move from t1 to t2 than they were willing to pay to move from t2 to t1.	Lowenstein & Prelec, 1992, p. 124.
Variance from future expectations	Individuals tend to consistently overestimate actual utility gains and losses when considering future events.	Gilbert, 2007, p. 102.
Sequence effect	Individuals generally exhibit a preference for a sequence of increasing payoffs that total to the same amount as decreasing payoffs.	Read, 2004, p. 435

Utility preference research investigating the impact of both risk and time generally focuses on a single attribute, money, as the underlying source of utility. Another stream of research, however, focuses on multi-attribute utility functions. The challenge presented by this research is that of mathematical tractability. Generally, multi-attribute functions pose little problem provided that the utility from different attributes is linearly additive, i.e.,

(1) $U(x_1,x_2,\ldots,x_n) \equiv U_1(x_1)+ U_2(x_2)+\ldots+ U_n(x_n)$

Where interdependencies exist, however, the mathematics of utility maximization becomes much more complicated. For example, if an individual's utility from acquiring a bottle of foreign beer simultaneously depends upon the ability to acquire a bottle opener, then the utility of neither can be computed independently (particularly if no such opener is required for a domestic beer). One way of handling such problems mathematically is to include cross products in the utility function (Keeney, 1972). Unfortunately, as attribute interdependencies in the utility function grows, closed form solutions become impractical (Bell, 1979).

One approach that has been proposed to address the complexity of multi-attribute interdependency has been to use multi-attribute functions, referred to as objectives (Keeney, 1988, p. 471) or need-based commodities (Becker, 1976, p. 134), as arguments to the utility function. These functions, in turn, depend on actual resources. This approach allows us to construct a hierarchy of objectives that are independently summed within the utility function. The approach also forms the underlying basis of the analytical technique referred to as goal programming, a close cousin to linear programming, in which the object is to achieve:

(2) $\mathrm{Max}_{x \in X}\, U(f(x))$

In this notation, x is a particular set of attributes from the set of all feasible attribute combinations X, *f(x)* is a collection of objective functions $f_1(x)$, $f_2(x)$,…,$f_n(x)$, and U is a function that determines decision-maker utility (Dyer, 1972, p. 63). In contrast to utility research dealing with a single attribute, which has tended to focus of exploring how decision-maker preferences are impacted by risk and temporal proximity, much of body of multi-attribute utility research has been devoted to exploring the theory and mechanics of finding the state of maximum preference when a complex set of objectives is available to the decision-maker.

Motivation and Goal Setting Theory

When viewed in the context of the management field, expected utility is essentially a measure of a state's motivational potential. Stated another way, the underlying axiom of utility theory is that an individual will be motivated to make the decision (or set of decisions) yielding the state of maximum expected utility. Motivation, however, has been the subject of many investigations within the management literature—most of which bear little or no surface resemblance to neoclassical utility theory. Perhaps the most important of these research streams is goal setting theory (Locke, 2004, p. 124).

As its name suggests, the concept of a goal is central to goal setting theory. Goals possess a number of characteristics that have been found relevant in empirical research. These include:

- *Performance goals versus learning goals.* Performance goals relate to task outcomes. Learning goals (a.k.a. mastery goals) involve the development of individual skills.
- *Approach versus avoidance goals.* Approach goals are those where the individual strives to achieve a particular consequence. Avoidance goals involve attempting to prevent a particular consequence (e.g., a failing grade in a course).
- *Distal versus proximal goals.* Distal goals are desired outcomes, whereas proximal goals may be sub goals established as part of a plan to achieve a desired outcome.
- *Goal source:* Goals may be externally established, participatively established, or individually established.
- *Goal specificity.* The degree to which goal achievement is clearly defined. Within performance goals, subcategories include: a) ability goals, confirming or demonstrating the individual's skills, b) normative goals, where relative performance is targeted, such as coming in first place, and c) outcome goals, which involve more objective standards of performance (Grant & Dweck, 2003). Thus, a goal may consist of a specific target (e.g., sales of $150,000), a relative target (e.g., become a top 5 performer), or an open-ended target (e.g., sell as much as you can).

Goal setting theory posits that individual motivation can be explained and directed almost entirely through the goals that have been either internally or externally established. Unlike earlier motivational theories such as expectancy theory (Vroom, 1964)—which views motivation in terms of valence (how positive or negative an outcome is) and expectancy (the likelihood of an outcome)—goal setting theory proposes that the actual presence of a well defined goal, as opposed to some underlying psychological need, is critical to establishing motivation (Bandura, 1991, p. 264; Locke, 1978). In its simplest form, then, the relationship can be presented as follows:

(3) State → Need → Goal → Motivation → Action

The resemblance of this model to the earlier utility-based decision model, presented in Figure 1, is obvious.

The goal setting literature is huge (e.g., over 100 different tasks, involving over 40,000 subjects, have been studied; Locke, 2004, p. 124) and has successfully demonstrated, in many contexts, how individual goals are instrumental in establishing motivation. Some important findings relating to the present chapter are summarized in Table 2.

In considering the Table 2 findings, it is interesting to note a number of parallels between goal setting findings and some of the anomalies presented earlier in Table 1. For example:

- The impact of framing (i.e., how a choice is presented impacts decision-maker preferences) mirrors that of priming in goal-setting research.
- Significant differences between behaviors relating to gains versus losses.
- Both literatures observe a proximity effect in which closeness (e.g., in time, salience) weighs disproportionately on the individual.
- Both literatures find that low probability outcomes are very different from impossible outcomes in how they are perceived by decision-makers.

Table 2: Important findings in goal-setting theory

Finding	Description	Example References
Priming	By unconsciously stimulating certain aspects of a goal, for example through having subjects read through a list of positive and negative words prior to participating in an experiment, substantially different goal performance and satisfaction may be realized.	Stajkovic, Locke, & Blair, 2006, p. 1175
Approach vs. Avoidance	Eagerness increases as you near completion of an approach goal, vigilance increases as you near completion of an avoidance goal.	Forster, Higgins, & Idson, 1998, p. 1129.
Specificity	Goals that are specific and difficult lead to better performance than a vague goal or no goal at all.	Latham & Locke, 2006, p. 332.
Mastery vs. Performance	Goal striving leads directly to enjoyment for mastery (learning) goals, and indirectly—through mental focus—for performance goals.	Lee, Sheldon, & Turban, 2003, p. 262
Commitment	Performance grows with goal commitment, especially for difficult tasks.	Klein, Wesson, Hollenbeck, & Alge, 1999, p. 886
Proximity	People exert more effort to achieve goals where progress has already been made, referred to as the "endowed progress effect".	Nunes & Drèze, 2006, p. 510
Difficulty	Increased goal difficulty leads to increased motivation and performance for approach goals, provided the goal is achievable, but less so for avoidance goals.	Janssen & Van Yperen, 2004, p. 377
Participation	Goals provide an important motivational regardless of whether or not the individual has participated in setting the goals. In many cases, participation doesn't appear to matter.	Latham & Steele, 1983, p. 416
Goals vs. Needs	Goals are better predictors of performance than personal achievement needs.	Bandura, 1991, p. 264

Another important parallel between goal setting research and utility theory involves the notion of limited attention. In utility theory, as previously noted, this manifests itself in the form of bounded rationality leading to constrained search behavior. In goal setting research, the implicit assumption is that multiple goals may be available and that commitment to a particular goal is critical to motivation (e.g., Klein, 1989, p. 886; Wofford, Goodwin, & Premack, 1992, p. 609). Within goal setting theory, this notion of goal intensity is also integral to a number of control theories of goal setting and motivation, which include both conscious and unconscious components (e.g., Johnson, Chang, & Lord, 2006). Researchers have also argued that goal specificity and intensity can be a major drawback to the application of goal setting research in practical settings—individuals, in fact, tend to ignore the potential adverse consequences of achieving a goal that has become firmly established (Ordonez, Schweitzer, Galinsky & Bazerman, 2009).

The goal-setting perspective is particularly adaptable to the informing system model because goals represent a central component of tasks (Gill & Hicks, 2006). Thus, if we can relate utility to goals, then we can also relate the role played by informing in the task completion system to utility.

A Goal-Based Utility Decision Model

As described earlier, motivation can be characterized as the impetus to maximize expected utility. If one accepts the findings of goal setting research it therefore stands to reason that a utility function could be constructed using goals, rather than other attributes (such as money), as its arguments. The validity of such a function would depend on several axiomatic assumptions, namely:

1. At any given time, an individual holds a set of conscious goals that can be articulated. Such goals may derive from many sources, including individual needs and external sources, such as the well-being of friends and family, the goals of organizations and communities with which the individual is affiliated, and even broader sources, such as spiritual goals, national goals, and environmental goals.
2. Utility derives from two processes: the direct satisfaction of needs and progress in the pursuit of the individual's goals, both

in absolute terms and relative to expectations. For the purpose of the model, needs are treated as concrete biological goals (Politser, 2008, p. 30), allowing all utility to be treated as arising from goal-based sources.

3. Attending to all goals concurrently would exceed the individual's processing capacity by many orders of magnitude. As a consequence, mechanisms for prioritizing, selecting, scheduling, and refining active goals are critical elements of reasoned behavior. These come in two forms: unconscious processes that establish preferences and heuristics—both specialized and general-purpose—that tend to be consciously applied. We refer to the latter as meta-reasoning behaviors.
4. As a result of axiom (2), we may assume that the decision to engage in explicit meta-reasoning behaviors is also goal driven. Goals of this type will be referred to as meta-goals.

Of these axioms, the second needs the most justification. Through introspection, most of us will probably concede that satisfying certain biological needs—such as hunger—often provides a source of utility. In nearly all animal species, that may well be the end of the story. One of the key differences between human and animal cognition, however, is the ability to think about the future (Gilbert, 2007, p. 4). To do so, we have developed specialized brain areas, such as the frontal lobe, whose principal function appears to be planning (Gilbert, 2007, p. 13). Furthermore, biological evolution tends to take such newly developed capabilities and superimpose them on top of existing capabilities, meaning that both planned and unplanned actions exist in parallel. In fact, it took considerable time for scientists to discover that a damaged or disconnected frontal lobe—such as occurs when a patient has a lobotomy—typically results in inability to plan; patients otherwise seemed quite normal (Gilbert, 2007, p. 11).

In addition to providing the capacity to plan, however, evolution needed to evolve a corresponding drive to use that capacity. One consequence of this seems to be that the frontal lobe can also be a major source of anxiety (which is why lobotomies were performed, since cutting the connection to the frontal lobe produced immediate declines in patient anxiety unobtainable through other means; Gilbert, 2007, p. 13). What the goal-based utility model therefore proposes—based upon both physiological evidence and the extensive goal-setting literature—is that goals provide an organizing framework around which most planning takes place and that utility, both in the form of reduction of anxiety and positive satisfaction, is derived from pursuing such goals.

The actual goals driving the goal-based model would result from a number of sources. Goals are created as responses to underlying needs, consistent with the goal-setting model. Examples of such needs include the drive to acquire, to bond, to learn, and to defend (Lawrence & Nohria, 2002). Even lower level need-based goals—such as those towards the bottom of Maslow's hierarchy—would routinely arise from fundamental biological drives (e.g., hunger, sex, security, social interaction) as a consequence of planning for future satisfaction of those needs. Where planning is not required, a direct path from need satisfaction to utility can occur. The model would predict, however, that the individual's utility gain from directly satisfying a need versus progressing towards a conscious goal derived from that same need could be quite different. This is consistent with findings that reasoning about a goal changes its utility (e.g., Dijksterhuis, Bos, Nordgren, & van Baaren, 2006).

Higher levels of the need hierarchy, much more uniquely human, would drive the formation of other goals. Fundamental desires, such as those for power, independence, acceptance, and status (Reiss, 2000), would drive the formation of achievement goals, such as career advancement. Other desires, such as curiosity, order, and tranquility (Reiss, 2000), could lead to a drive to reduce uncertainty. These higher level goals would tend to be conscious in form.

Meta-reasoning processes, invoked by the drive to reduce uncertainty, would focus on goal identification and planning-related activities such as prioritization and scheduling. For example, the environment may present the individual with an unexpected opportunity stimulus. In some cases, a special-purpose script—conscious or automatic, acquired through past experience or education—for translating that stimulus into a goal and creating an action plan may exist. Because such an opportunity can come in many shapes and forms, however, each decision maker must also possess a set of general purpose heuristics for recasting novel stimuli into utility preferences and action plans. As previously noted, general-purpose preference heuristics have been the subject of considerable study (e.g., Kahneman, Slovic, & Tversky, 1982; Payne, Bettman, & Johnson, 1993). Where preference determination is required, unconscious and conscious processes may both be involved. In fact, it has even been shown that for certain types of choice problems relying on unconscious processes may lead to better results than applying available heuristics (Dijksterhuis et al., 2006; Gladwell, 2005; Wilson & Schooler, 1991). Planning heuristics, on the other hand, would nearly always be conscious. These would include general purpose strategies such as decomposing a complex goal into subgoals (e.g., Simon, 1981) and various search heuristics (e.g., Newell, 1990).

Particularly critical to the goals-based model is the notion that goals can also be adopted from other individuals and communities with whom the decision maker interacts. Simon (1992) argues, for example, that such adoption of communal goals is critical in explaining the formation of organizations and altruism. It would also be nearly impossible to explain behaviors such as enthusiasm for a particular sporting team, religious tithing, or nationalism without the notion of communal goals. Simon quotes Gary Becker as saying:

> I decide whether to turn off my reading lamp in bed by comparing the utility of my pleasure in reading with the amount of utility I receive from my wife's being able to sleep. (Simon, 1992; p. 74)

Experimentally-based psychological research seems to confirm that altruistic goals are a source of motivation separate from egoistic goals (Batson & Shaw, 1991). There are also evolutionary arguments that can be made that altruistic behavior could, ultimately, enhance individual fitness (Gandolfi, Gandolfi, & Barash, 2002). Because cooperative behaviors can increase efficiency (e.g., time spent defending your land against competitors is time that cannot be spent farming) and short-term altruistic behaviors (e.g., helping a neighboring family defend their land against competitors) would tend to promote such cooperation over the long term, drives that lead to the formation of altruistic behaviors could form an evolutionarily stable strategy (ESS). This does not necessarily imply that the "altruism gene" would be universally present throughout the population. Rather, it means altruistic individuals (competing against entirely selfish individuals, such as sociopaths) would exhibit sufficient fitness to remain a percentage of the overall population indefinitely.

The notion that we, as human beings, might have an underlying biological drive leading us to derive pleasure from participating in and observing progress towards the goals of others is both intuitive—how could we enjoy reading a novel or watching a sporting event if such a mechanism were not present?—and profoundly subversive, potentially undermining important elements of the theoretical justifications for both transaction cost economics (e.g., Moschandreas, 1997) and agency theory (e.g., Simon, 1991). There also appears to be a physiological basis for believing how such an affinity could exist. Within the brain, mirror neurons respond to observing the acts of others in much the same manner as they do when we perform the acts ourselves (Shermer, 2008, p. 132). Thus, it would make sense to speculate that their presence could also lead to utility as we observe external goals being achieved.

A goal-based utility function would differ in purpose from other objective-based utility functions (e.g., Dyer, 1972; Keeney, 1988) mainly in that its principal objective would be to describe and predict individual behaviors, rather than to establish an approach whereby utility could be maximized. It differs from neoclassical utility functions—which are not precluded from incorporating goals as attributes (Simon, 1992)—in that it proposes that an understanding of individual goals and meta-goals is a prerequisite to meaningful explanations and predictions of preferences and decisions. Conceptually, this difference can be represented by adding a stage that specifically maps outcome sets to the goals that they serve as part of the utility maximization process. For example, if we assume that a decision-maker is pursuing M different goals under conditions of uncertainty, we might represent this as illustrated in Figure 2.

A critical difference between the goal-based model and the neoclassical model stems from the concept of goal allocation. The idea here is that a given set of outcomes may map to different utilities depending upon how the changes are allocated among the decision maker's various goals. For example, if a decision maker's gas tank is empty, the first step in going on any road trip would be to stop at the gas station. What the goal-based utility model would predict is that the "utility" associated with choosing the action of going to the gas station will depend heavily on what goal or goals (e.g., what destination, what anticipated activities are associated with the destination) the decision-maker intends to pursue upon completing the gas filling action. Naturally, the mapping between actions and utility is one-to-one if a given action can only support a single goal. If, on the other hand, a particular action (e.g., getting an undergraduate degree) supports multiple longer-term goals that are mutually exclusive (e.g., getting a job, going on to medical school, going on to law school), then the utility associated with making progress towards the degree may depend heavily on the relative priority associated with each of the longer-term goals. As priorities change, so would utility. Furthermore, the goal-based model suggests that framing "anomalies" in which decision maker's express inconsistent preferences for the same resource-based outcome are better explained in terms of differing goal allocations being in force rather than as demonstrations of decision maker irrationality.

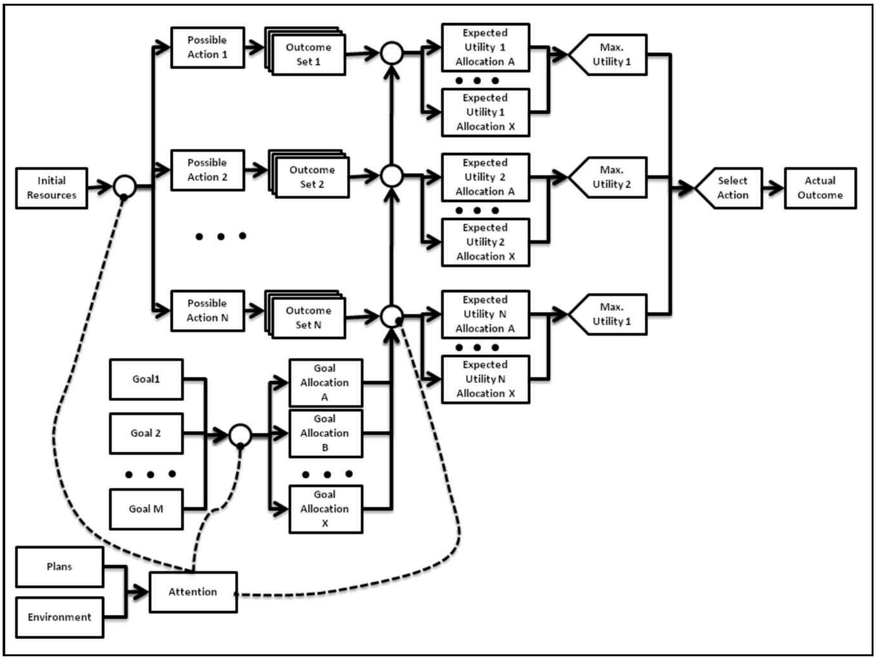

Figure 2: Goal-Based Utility Decision Model

The model in Figure 2, as presented in its purest form, might easily be described as "pegging the meter" of cognitive implausibility. The number of possible goal allocations is, effectively, infinite if we allow allocations where each goal is given a percentage priority. Even if we limited ourselves to rank ordering goals, if there are M goals there are M! (M factorial) allocation combinations. To reduce the choice process to cognitively manageable proportions, we therefore need to postulate mechanisms that drastically reduce the number of alternatives being considered. Thus, the model postulates that at any given time we are attending to a relatively small number of goals. These goals are determined by existing plans and environmental stimuli. The proposed impact of attention is to:

1) Suppress the number of actions we consider, leaving only those relevant to goals we are attending.
2) Suppress the number of allocations that we attend to, focusing only on those with attended goals
3) Suppress the number of allocations we consider for each outcome set, ignoring those where the goal-outcome connection is expected to be weak.

In Figure 2, these are shown as inhibiting links (dotted lines ending in a circle) from the attention box to the circles where alternatives and combinations are generated.

In the most extreme case, the inhibitory effect would lead to focusing on a single goal, devising a sequence of actions (i.e., a plan) towards achieving that goal and experiencing utility directly proportional to the progress towards the achievement of that goal (and nothing else) as the sequence of activities continues. In such a circumstance, the utility model could—in effect—converge to the economic utility model, as progress towards the goal might be a function of external values (e.g., how many papers do I have left to grade?).

In a more realistic scenario, the decision maker would have multiple goals but these would differ in the degree to which they are active. A large percentage of actions would be a consequence of goal-directed plans, but periodically a more complete reassessment of available actions would be made in response to conditions such as variances between actual and expected outcomes within a plan, plan completion, need-based signals activating other goals (e.g., hunger leading to the goal of going out to eat), or external stimuli activating other goals (e.g., while shopping for one item you notice an item you also wanted on sale). The decision to engage in plan reassessment can be referred to as activating a meta-goal and, according to the model, our choice to engage in such planning activities would only occur when we perceive that doing so will lead to a successful plan (providing utility by moving us towards the meta-goal) that will improve our progress towards other goals or, possibly, where the act of planning serves to reduce our anxiety regarding how long it has been since we last planned. The price we pay for this form of bounded rationality is that the utility experienced as a consequence of our actions will depend heavily on the specific goals we are attending, meaning that the same resource state could lead to different utilities based upon what goals are being pursued: a classic scenario for framing.

In considering how the attention and goal allocation elements that contribute to the utility function might be constructed, goal setting research makes it abundantly clear that we would need to consider:

- The individual's commitment to the goal (e.g., Klein et al., 1999)
- The degree to which the individual is consciously attending to the goal. For example, goal priming has repeatedly been shown to influence preferences and decisions in many experimental settings (e.g., Stajkovic et al., 2006)
- The likelihood of achieving the goal, which may be a function of both perceived goal difficulty (e.g., Janssen & Van Yperen, 2004) and considerations of external uncertainty.

As a preliminary model, based on the existing literature, the attention signal feeding into the utility function might—within its arguments—partition individual goals into categories, shown in Figure 3. Of the five categories stacked vertically, the highest category, attended goals, would consist of the one (or, possibly, few) goals actively being processed by the individual at a given time (i.e., in working memory). The next category, active goals, consists of goals that the individual is actively pursuing but which are not currently attended. For example, a pre-med undergraduate student may have getting into medical school as an active goal without concentrating on it every waking moment. The middle category, pending goals, represents those goals to which the individual has significant commitment but towards which no action has yet been taken. An individual might, for example, have a goal of eating at some specific restaurant the next time he or she visits New York City yet not engage in any action towards fulfilling that goal until the visit actually occurs or is planned. The fourth category, possible goals, represents those goals to which the individual has no firm commitment but to which the individual has some attachment. Such a category is necessary in order to incorporate the construct of "hope", which has been observed to have powerful psychological impact (e.g., Snyder, 2002). The final category on the stack, impossible goals, represents the collection of goals that might have served to motivate the individual but that have been deemed infeasible.

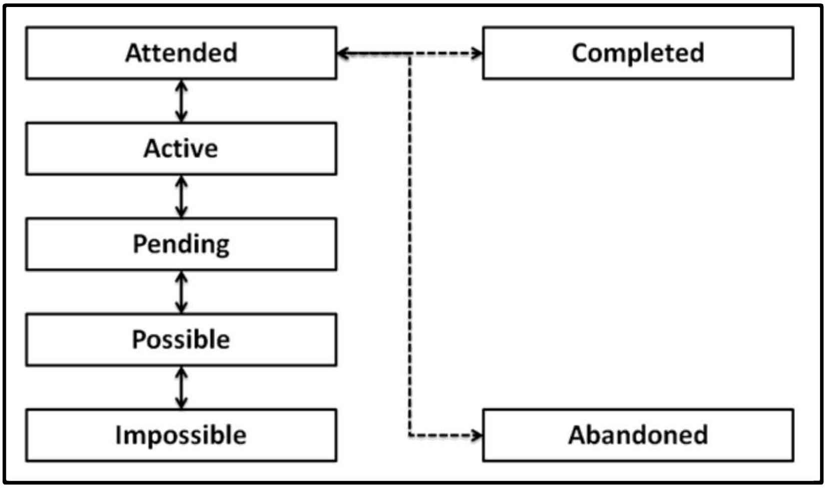

Figure 3: Goal Attention Levels

The remaining two categories, completed goals and abandoned goals, would hold goals no longer active, either by virtue of completion or by virtue of failure to achieve or abandonment. In both cases, we would expect a residual effect on utility that would rapidly decay with time, since utility effects of success and failure to achieve goals tend to decline quickly—indeed, more quickly than we expect (Gilbert, 2007, p. 102). We may, however, choose at some point to revisit these goals mentally and re-experience some of the same utility—to relive our success or, perhaps, to learn from our failures (Elster & Loewenstein, 1992). Doing so appears to be possible because much of the sensory and emotional circuitry the brain uses when we experience something is also used when we recall the same experience (Gilbert, 2007, p. 120).

Learning Architecture of the Utility Function

The previous section focused on how attention impacts utility in the context of an overall decision-making model. In this section, we consider more closely the type of cognitive architecture required to implement the utility function itself. In the goal-based utility model, utility would be a function of at least three distinct elements:

1. The attractiveness of the goal outcome (roughly equivalent to the valence in expectancy theory), which in turn would be influenced by goal type (e.g., learning vs. performance, approach vs. avoidance goals, specific vs. general goals will tend to have different profiles).

2. The individual's perception that he or she is making progress towards the goal (including activities that create a more concrete path towards the goal, such as planning). Where the individuals own actions are seen as being instrumental in achieving such progress, the utility would be even greater, as the desire to exercise control is another example of a fundamental human need (Gilbert, 2007, p. 20).

3. The degree of commitment to the goal, as approximated by its goal attention level (Figure 3), with goals moving up (towards attended) increasing utility and moving down (towards impossible) reducing utility. This is consistent with the observed psychological phenomenon of preference increasing as choices become increasingly irreversible (Frey, Kumpf, Irle, & Gniech, 1984; Gilbert, 2007, p. 183-184). This effect could also lead to the observed phenomenon of increased effort being applied towards goals that are approaching completion (e.g., Nunes & Drèze, 2006).

As mentioned in the introduction, a major weakness in any utility model is the failure to incorporate a mechanism for learning. Specifically, as humans we have the ability to establish preferences in both familiar and unfamiliar settings. Any plausible utility model therefore needs to establish a mechanism capable of handling both types of preferences.

To accommodate learning, we can view the utility function as existing on three levels, depending upon the familiarity of the situation. At the lowest level—that level where the context is so familiar that utility-based choices are unnecessary or can be made without conscious effort (e.g., automated activities; Shiffrin & Dumais, 1981) —the function might look something like that proposed by economists, with arguments consisting of a set of values and little need to consciously attend to goals. In this condition, utility becomes a type of stimulus-response phenomenon where it is unlikely that the decision maker will be able to justify his or her utility. The pleasure derived from engaging in a practiced skill (e.g., playing the piano) might be an example of utility at this level. In the previous section, this was described as the single-goal focus.

The intermediate level, which would be particularly consistent with the goal-based decision-making model described in the previous section, would have arguments consisting of specialized goals, with utility deriving from activation levels and goal progress. At this level, decision makers should be able to offer an explanation of their decision-making process, since goals are conscious in nature. This would also be the domain in which the findings of the goal setting literature would be most applicable.

At the highest level, we find ourselves encountering unfamiliar situations. For this level, there is a particular need for general-purpose mechanisms for estimating utility. Such a mechanism can be constructed using detectors—cognitive units that identify choice attributes that are expected to contribute to or detract from utility—and accumulators, which consolidate signals from detectors and other accumulators in order to assess the overall fitness of a particular choice.

There is a long history of cognitive models—originally focused on word identification—that have employed the detector-accumulator model. The original architecture proposed was Pandemonium (Selfridge, 1958), which treated cognitive architecture as a series of layers. At the bottom layer, feature detectors (referred to as daemons) identified letter features—e.g., slanted lines, vertical lines, horizontal lines, and arcs—that sent signals to a second layer containing accumulators associated with each letter that, in turn, sent signals to word accumulators that identified words. This original model was then extended in HEARSAY and then in the interactive activation model (McClelland & Rumelhart, 1981; Rumelhart & McClelland, 1982). More recently, the leaky accumulator model (Usher & McClelland, 2001, 2004) has been specifically applied to explaining precisely the types of inconsistency of choice problems that were identified in Table 1.

Because our interest here is in understanding how utility behaves in general, we'll focus on ways in which these models are similar, rather than on how they are different. In common, all the models assume:

- Parallel processing of inputs.
- The existence of feature detectors and the ability to develop new feature detectors.
- The existence of layers of elements (e.g., detectors, accumulators) at different levels of abstraction.

Common to the later models, heavily influenced by findings in neural networks, are the following additional similarities:

- A substantial amount of "knowledge" is contained in the strength of linkages between system elements.
- Linkages can both excite and inhibit accumulators and detectors
- Learning occurs through changes in the strength of connections between elements.

Where models tend to diverge is in relation to the process by which links change, the degree to which symbolic versus connectionist processes dominate, and the nature of activation signals (e.g., linear versus non-linear). For the present purposes, however, we need not dwell on these differences; ultimately these will most likely be settled in the domain of neuroscience.

Our overall utility model for unfamiliar choices is illustrated in Figure 4. At the bottom layer, we have a set of generic goal feature detectors that can be applied to nearly any choice problem as well as a few examples of problem specific goal feature detectors. These detectors would be applied to a specific choice to identify attributes relevant to satisfying goals. The next level has a collection of generic goals—which is to say goals that are always waiting to be achieved—plus specific goals, with a few examples provided. The most important source of activation for nodes on this level is signals from the feature detectors of the lower level. Thus, the arrow going from the *Gain* feature detector to the *Wealth* goal node signifies that when a gain is detected in a particular choice, activity in the *Wealth* node increases. On the other hand, the inhibiting connection (ending with a circle instead of an arrowhead) between *Loss* and *Wealth* signifies that a detected loss will decrease activity in the *Wealth* node. The next level is the utility level, which takes signals from the various goals activated at the goal level (signified by the cluster of arrows on the left of the figure going into the *Valence* node) and sums them to produce a valence whose strength signifies utility. Finally, the top level includes factors that may ultimately impact utility, such as plans and visceral factors (e.g., decision-maker needs such as hunger, which we would expect should increase the utility of any options that lead to food).

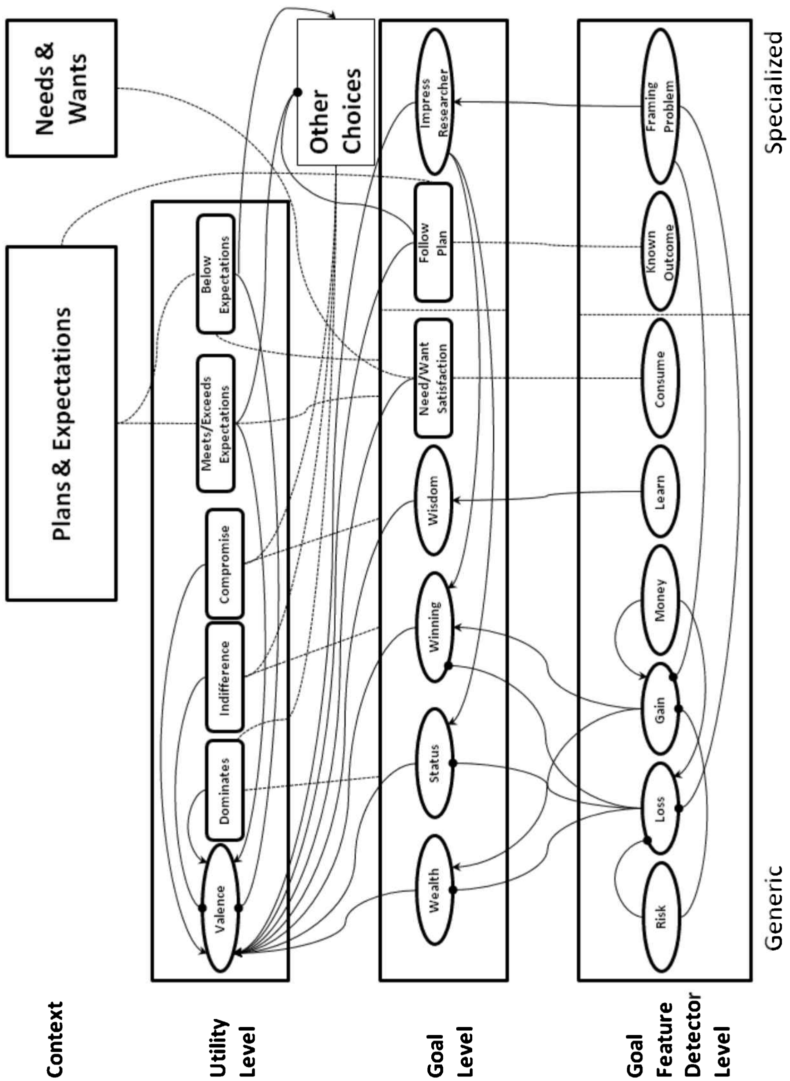

Figure 4: Multi-level utility model emphasizing unfamiliar problems

Consistent with activation models, such as the interactive activation model (McClelland & Rumelhart, 1981) and the leaky accumulator model (Usher & McClelland, 2004), there are a number of aspects of the model that extend beyond the basic movement of activation upwards from layer to layer. At the bottom layer, for example, the *Risk* detector sends inhibiting signals to both the *Loss* and *Gain* detectors. This means that as risk is detected, the strength of both gain and loss signals will be reduced, since they lack certainty. Some nodes are also constructed to be comparator nodes, shown as rounded rectangles. These nodes take connections, shown as dotted lines, from various sources and produce an activation or inhibition signal based on some comparison. For example, the *Need/Want Satisfaction* comparator node on the goal level takes consumption (or expected consumption) signals from the detector level—simplified to appear as a single node, although many types of consumption could obviously be involved—and compares these to signals from the want/need area (also simplified as a single line). Activation signals are then produced reflecting the degree to which consumption (or other activity) associated with the choice option being considered matches the current need profile.

Particularly strong support for a model such as the one proposed is provided by framing experiments. The framing phenomenon occurs whenever the choice between identical outcomes is influenced by how the alternatives are presented. The same phenomenon extends to situations where the presence of irrelevant or "decoy" alternatives exert a significant impact on our choices. Framing is particularly vexing to traditional economic utility models because it violates the mapping between outcome and utility.

A typical framing situation—and there are numerous examples of these—is presented in the form of two sets of choices that lead to the same outcome and but are presented in different ways. Consider, for example, the following (adapted directly from Tversky & Kahneman, 1988, p. 173-174):

First choice problem:

Assume yourself richer by $300 than you are today. You have to choose between:

A. A sure gain of $100
B. 50% chance to gain $200 and 50% to gain nothing

Second choice problem:

Assume yourself richer by $500 than you are today. You have to choose between:

A. A sure loss of $100
B. 50% chance to lose nothing, 50% to lose $200

The actual results of this experiment were that most (72%) chose A in the first problem, while most (64%) chose B in the second. This presents a bit of a problem for any utility model based on values, since—in fact—options A and B in both choice problems lead to precisely the same outcome: a $400 gain in choice A, a 50-50 distribution between $300 and $500 in the case of choice B.

Now, let's consider this experiment under the architecture that was illustrated in Figure 2. First, however, we need to make some assumptions. We begin by assuming that we evolved as a fundamentally peaceful species that needs to engage in three basic activities to survive: acquiring resources, consuming resources, and defending resources from threats (which might include predators, less peaceably evolved humans, and more mundane threats such as spoilage and pests). Not coincidentally, these resemble the capabilities viewed as necessary for the general-purpose agent: offense, defense, and a reservoir (Holland, 1995, p. 101). Supporting this conjecture is ample psychological evidence for an asymmetry between gains and losses, incorporated into prospect theory (Kahneman & Tversky, 1979) and SP/A theory (Lopes & Oden, 1999) and supported by some brain studies (Polister, 2008, p. 81). In fact, observed reactions to loss and gain are fundamentally different (Gilbert, 2007, p. 145), as are our attitudes towards what we already have and don't have (the "endowment effect"; Ariely, 2008, p. 129). Thus, there is no reason to expect that activation signals from *Gain* and *Loss* detectors will be symmetrical. We also expect the *Risk* detector node, which acts to suppress the activation of the remaining frames in the event that uncertainty is detected, will generate inhibition signals varying roughly with probability but less finely tuned (Slovic, Finucane, Peters, & Macgregor, 2006).

Our second assumption is that we have no specialized goal frames for evaluating gambles (gambling being unusual in that it is an activity where acquisition and loss of resources occur through the same process) and, most importantly, that we have no specialized avoidance goals that relate to being embarrassed by the types of inconsistencies produced by framing experiments. We will later consider how such a goal, already shown as a "specialized" node in Figure 4, might impact utility.

Under these circumstances, when we consider our first choice problem, we'd expect the following:

- Option A: *Gain* node sends out strong signals. All other detectors keep quiet.
- Option B: *Gain* node sends out signals that are suppressed by the *Risk* node.

Based on this model, activation would likely be higher for Option A in the event that risk adversity exists, consistent with the actual findings. What this would imply is that the *Risk* node sends out inhibitory signals stronger than justified by probabilities alone. Now, let's examine the second pair of choices:

- Option A: *Loss* node sends strong inhibiting signals. *Gain* node sends out a positive signal. All other goal frames keep quiet.
- Option B: *Loss* node sends signals that are inhibited by the *Risk* node. *Gain* node also sends out the same positive signal.

If the inhibiting impact of the *Risk* node has the same inhibitory strength on *Loss* node as it did on *Gain* node, the second option is likely to yield the stronger activation. If strengths differ, a different pattern of responses may emerge (which is also consistent with the fact that not all subjects chose the dominant pair of options).

Naturally, all this changes once the experimental subject has specialized knowledge of framing experiments. Under these circumstances, it is very likely that the subject will recognize the familiar pattern common to such experiments. This specialized *Framing Problem* detector will then activate the *Impress Researcher* specialized goal node and send inhibitory signals to the *Gain* and *Loss* nodes so that they do not confuse the subject—as they were originally intended to do by experimental design. As a consequence, the subject will therefore make the same choice in each pair (unless some other specialized goal node exists, such as a "rebellion goal" that activates based on detecting an opportunity to disrupt the experiment).

A particularly pervasive category of framing occurs as a consequence of detecting favorable comparisons and similar options among choices. In the case of favorable comparisons, when three options are presented to a decision-maker and two are similar, with one clearly dominating the other, decision-maker preference tends to skew towards the dominant option in the pair, regardless of the characteristics of the third. This is referred to as the attraction effect (Usher & McClelland, 2004). In the case where three options are presented and two are similar (with neither dominating), decision-maker preference skews towards the third, non-similar option. This is known as the similarity effect (Usher & McClelland, 2004). In the case where one option could be viewed as a compromise between the other two, that option is disproportionately selected. This is known as the compromise effect (Usher & McClelland, 2004). Interestingly, all three of these observed behaviors represent reasonably sensible approaches to highly unstructured choice making. The attraction and compromise heuristics tend to assure that the option chosen will be better than at least one of the other two—improving the decision maker's odds. The similarity heuristic, on the other hand, brings decision-making to a close more rapidly.

In Figure 4, these three phenomena are handled by generic comparators at the utility level. The detection of option dominance or of an option serving as a compromise are both proposed to increase utility activation (the *Valence* node). Where an option is found to be indifferent to other options—the similarity effect—utility is inhibited.

It should be noted that Figure 4 is provided to illustrate the architectural structure only and is by no means intended to be complete. In fact, a number of other general-purpose goal nodes and goal feature detectors can be postulated based on research conducted in a variety of contexts. For example, we might postulate detectors that feed into an "Engaging Activity" goal node that include:

- Identify situations where we gain control (+) and lose control (-) as a consequence of a decision, since control has been found to be a powerful motivator (Gilbert, 2007; Gill, 1996).
- Identify situations where the expected consequences of a decision lead to cognitive arousal that is likely to be too low (-), too high (-) or suitable for optimal engagement (+), with arousal being another general motivator (Gill, 1996).

- Identify variety in associated rewards and activities (+) versus uniformity (-), supported by the job enrichment literature (Hackman & Oldham, 1980) and as demonstrated by finding related to individual preferences for rewards (e.g., Gilbert, 2007, p. 129).

We could also postulate an altruistic goal node (e.g., Batson & Shaw, 1991) that would have associated feature detectors. Another example might be a detector that reacts to the particular presence of money, consistent with a large number of examples by Ariely (2008), who found that its mere mention was sufficient to "cause market norms to emerge" (p. 74). This might be an example of a goal frame detector that amplifies the signals from other detectors (e.g., gains, losses).

For the proposed architecture to be plausible, as specialized learning progresses, the generic model should exhibit convergence with our intermediate (specialized goal-driven) and low level (stimulus-response) utility models. Such convergence is envisioned happening as follows. Specialized goals and goal detectors that are acquired through experience would inhibit irrelevant or distracting general detectors and goal nodes, increase the activation of those that are relevant, and send signals directly to the valence. This would lead to utility deriving almost entirely from specialized goals. In addition, specialized comparator nodes would examine goal features and task state with respect to expectations associated with existing plans. As shown in Figure 4, these could act at multiple levels to increase activation where activities (detector level and goal level) were consistent with plan and where choices and outcomes were consistent with plans. They could also inhibit other choices where performance met or exceeded the active plan. Where inconsistency with plans was encountered, on the other hand, inhibiting signals could be sent to the *Valence* node and activation signals to other task choice valences could also be sent. This process would tend to lead to a change in selected action. Initially, such signals would reward goal progress in combination with other goals. Eventually, for highly routine tasks, these signals might suppress all other goal-related signals and drive utility for the entire process, leading to the predicted low level stimulus-response behavior.

It must be emphasized, once again, that Figure 4 is for illustrative purposes only. In a truly realistic neural model, connections, of varying strengths, would tend be much more dense between nodes and the nodes would be considerably less arbitrary in their names and functions. What the illustration does demonstrate, however, is that a multi-level architecture along the lines described is conceptually feasible, accommodates learning, and can explain many phenomena that are viewed as anomalies in traditional neoclassical utility models. These are the key elements of plausibility that need to be established for our purposes. The details of the example model—which are certainly oversimplified and likely to be wrong in many specific ways—would need to be verified and modified over the course of future research projects.

Divergences between Goal-Based and Neoclassical Utility Functions

Since adding explicit goals to a utility model increases its complexity when compared with neoclassical models, it would be hard to justify adopting a goal-based approach if the predictions of the two models did not differ in some non-trivial ways. For example, in many ways, the goal arguments of the proposed utility function are similar to Becker's (1976) commodities—something particularly true of the generic goal nodes proposed for the unfamiliar choice model. These commodities, however, are presumed to be need-based and relatively stable over time (Gandolfi et al., 2002). In contrast, the goal-based model anticipates a continually changing internal landscape of goals and considerable attention-driven variation in utility. Thus, while neoclassical models may be more appropriate for understanding aggregated macroeconomic phenomena, the goal-based utility model is distinctly focused on individual behavior, such as understanding and predicting preferences.

With respect to the framing behaviors, differences between the two models are immediately apparent. In the neoclassical model, the existence of a difference in utilities between two identical payoffs is a serious violation of the axioms and, therefore, can be viewed as irrational. In the goal-based model, on the other hand, such differences are expected, as would be preference reversal (e.g., Grether & Plott, 1979). Interestingly, whereas neoclassical models may concern themselves with the need to train decision-makers to reframe problems (e.g., Somon, 2004, p. 396), in the goal-based utility model the source of framing is viewed as a mechanism for coping with situational lack of structure. As familiarity with a situation increases, the mechanisms that lead to framing would be suppressed by more specific goals. In the informing system context, this would suggest that systems built around repetitive tasks might be less susceptible to presentation-related biases than might be expected based upon experimental results.

Another area where goal-based utility would differ from neoclassical models is with respect to time. As noted earlier in Table 1, neoclassical models have a great deal of trouble constructing realistic time preferences as a result of immediacy effects, inconsistent discounting, and variations in time preference for different magnitudes of rewards. In the goal-based model, we would expect a number of effects. For modest monetary reward amounts, we would likely have an intuitive—perhaps even unconscious—sense of how the money could be employed in achieving our currently active goals (i.e., what we'd spend it on). This would make immediate money particularly "valuable" in utility terms. That effect would wear off quickly with delays in payout, however, resulting in a pronounced immediacy effect. For much larger sums, we would generally expect the immediacy effect to be much less pronounced, since a large sum would normally require significant rethinking of goals in both the immediate and delayed payment cases. (As an exception to this, the goal-based model would also predict that the immediacy effect would continue to be pronounced under circumstances where the decision maker happened to have an attended or active goal that could efficiently benefit from a large infusion of cash). A further prediction of the goal-based model would be that immediacy effects would be less pronounced for delays in non-cash payouts, such as restaurant gift cards, since such a payout identifies the goal to be accomplished (quelling hunger) in both near and long term. (Again, the predicted exception would be in the case where the decision maker was hungry at the time the choice was presented.) In fact, we might speculate that it is the very fact that such gift cards encourage recipients to attend to goals that are more specific than money that accounts for their popularity with givers—as it is hard to understand why instruments that limit recipient flexibility would be given in preference to cash under any neoclassical utility model.

The relative importance of discounting also diverges between the neoclassical and goal-based utility models. In the neoclassical model, incorporating the time dimension requires the estimation of utilities at many future points in time and then incorporating these into the decision making framework. While the goal-based model does not necessarily preclude such elaborate calculations to establish time preference, it does not necessarily depend upon them. Although goals can be achieved either in the near or distant future, progress made towards such goals would contribute towards utility in the present. Savings, then, would not necessarily be treated as a form of deferred gratification (sacrificing current utility for future utility). Rather, the goal-based model would assert that the present utility gained from making progress towards the savings goal is greater than the utility that would be derived from current consumption. This notion is consistent with social self-regulation theory, which assumes "behavior is directed by cognized goals, not pulled by an unrealized future state" (Bandura, 1991, p. 248). There is also some biological evidence that delayed and uncertain outcomes employ a great deal of common circuitry in the brain (Politser, 2008, p. 54) and that our perceptions of differences in distant time are fuzzy (Gilbert, 2007, p. 107), much fuzzier than would be implied by the computations entailed in neoclassical discounting models.

Another important difference between goal-based utility and neoclassical utility involves the presumed impact of rising income. In neoclassical economics, the problematic "Easterlin Paradox" involves the observation that, across industrialized nations, overall happiness—which closely corresponds to utility—does not improve with national income although, within a particular country, happiness generally rises with income (Clark, Frijters, & Shields, 2008). Similarly, average national happiness does not necessarily rise as per capita income rises. This is problematic for any resource/consumption based utility function. The usual economic explanation involves postulating that it is relative income, both with respect to a set of peer individuals and with respect to one's own past performance, that actually produces utility (once subsistence needs have been met). Two comments can be made with respect to this paradox and its economic explanation. First, a goal-based utility model would predict minimal utility effects from rising income except to the extent that it permits individual goals—which could, of course, be dominated by wealth accumulation or consumption goals but which are likely to be much broader in practice—to be better achieved. The obvious exception here would be a predicted boost in utility as individual income rises just above subsistence, which would be the point at which many discretionary goals would start to become possible, an economic phenomenon that has been observed (Clark et al., 2008).

With respect to utility gains with rising income within a particular nation, the goal-based model would take a different perspective. Conceptually, the basic goal-based model appears as follows:

Goal Achievement → Utility

On the other hand, as a general rule, it would also make sense to predict that:

Goal Achievement → Higher Individual Income

Thus, a correlation between income and utility would be anticipated. That relationship would only be causal, however, where competitive goals vis-à-vis peers versus self represented an important part of the individual's internal system of goals. Furthermore, the intensity of individual versus collectivist goals appears to vary considerably across cultures (Hofstede, 2001). Thus, we might also expect considerable variation in the impact of relative income on utility across cultures.

A second point may also be made regarding relative income utility models in economics. Achieving comparatively superior performance "with respect to a set of peer individuals and with respect to one's own past performance" is—in fact—a goal. In the illustration of Figure 4, for example, it seems closely related to the generic goal of "Winning". Thus, perhaps inadvertently, economists have adopted a goal-based utility model in this context, even if not described as such.

Perhaps the greatest difference between the neoclassical and goal-based utility models can be characterized in terms of opacity of decision processes. The neoclassical model is constructed very much according to the behaviorist philosophy in which a stimulus is provided in the form of a set of alternatives, response is determined in the form of a choice, and relatively little attention is paid to the decision maker's self-reported internal thought processes. The advantage of such an approach, particularly for macro-economic purposes, is that errors in predicting individual decisions are likely to get aggregated away. Moreover, as previously noted, models that assume utility results from satisfying drives—particularly Becker's (1976) economic model and evolutionary models (e.g., Gandolfi et al., 2002)—would tend to be relatively stable and therefore suitable for mathematical analysis and modeling. Weaknesses in neoclassical models only become embarrassingly apparent when specific individual preferences and behaviors become the object of prediction.

The specific goal-based model—presumed most active for decisions that are neither entirely ill-structured (employing generic goals and detectors) nor completely programmed (involving automated, unconscious task performance and goal progress monitoring)—presumes continual adoption, modification, completion, and abandonment of specific goals. It therefore complements the neoclassical model by being entirely decision-maker directed. It involves analyzing information processing activities within the decision maker's head, making it a cognitive rather than behavioral model. Indeed, without knowing the decision maker's individual goals, it would be nearly impotent in its ability to make any useful predictions. Its advantage would, in principal, therefore lie in interpreting behaviors and making predictions at the individual level. Since informing systems are often designed around a particular individual or known set of individuals, it would be particularly appropriate for analyzing utility in these contexts.

Implications for the Informing Sciences

In the context of the informing sciences, there are a number of potential implications of the proposed utility model. Foremost among these is its influence on the value of information, a subject of considerable discussion in Gackowski's Chapter 4. In economics, the value of a particular item is frequently viewed in terms of its marginal utility, which is to say that the value of an additional item of X_i to a particular individual, mathematically described as:

$$dU/dX_i$$

Ideally, an individual would want to spend each new dollar that becomes available on the good that offers the greatest marginal utility for that dollar. It therefore follows that a rational individual should choose a basket of goods and services such that each marginal utility is proportional to its price.

Since one example of a good or service that a client might choose to purchase is information relating to a particular task, we would expect that the price he or she would be willing to pay would be proportional to the perceived marginal utility of that information. So far, we have not left the domain of neoclassical economics.

The particular impact of the proposed model occurs when the nature of the informing taking place is considered. As illustrated in Figure 5, the types of tasks that may be associated with an informing system can vary significantly. On the one hand, a system could provide routine informing on a familiar task. For example, a system might provide up-to-the-minute vendor price quotes, used to inform purchasing decisions. For such a system, the neoclassical utility model might work perfectly well—by determining how valuable it is to have such quotes (as opposed to acquiring them through other means), you should be able to gauge how much the client would be willing to pay for the informing. Issues such as goals or drives would not play a particularly important role, since the utility function involved would already be well-learned and largely tied to task progress. Thus, the motivation for informing of this sort is likely to be almost task-driven.

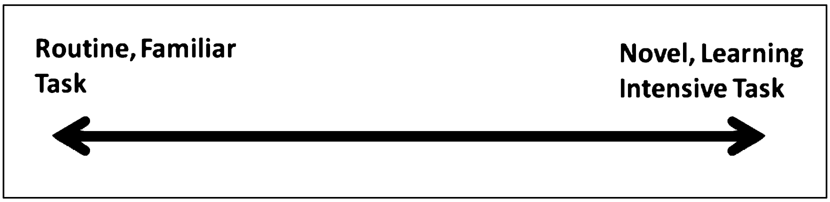

Figure 5: Continuum of informing tasks

At the other end of the continuum, the utility function would be entirely different and very much out of line with neoclassical models. Here, utility would derive from the client's perception that the informing will satisfy one of more of the generic drives and/or desires hard-wired into all of us. Such utility is likely to be highly vulnerable to framing effects and other cognitive biases, as discussed in the next chapter. It will also be substantially impacted by visceral factors, such as emotions, which alter activation levels and attention associated with the various nodes. We would also expect the strength of these drives to vary considerably between individuals (Reiss, 2000). As a consequence, we would expect utility at this end of the continuum to be highly volatile and therefore largely client driven.

In between the two informing extremes, we have the region where motivation—and hence utility—is principally a product of making progress towards task-related goals. In this region, it follows that the source of the specific goals that are established—which could be the sender, the client (or the client's supervisor), or even the task itself—will have the greatest ability to impact the perceived value of informing. It would also seem to be the area where the greatest potential to influence the informing process exists. For example, the leader who is able to get the client to commit to certain goals that require informing will thereby increase the utility of the informing process to that client. Such leadership is likely to be far less effective at the Figure 5 extremes. Where the task is routine, such goals are no longer needed. Where the task is so unfamiliar to the client that utility is dominated by generic drives, variability across clients will make it much harder to impact utility in a predictable way.

Conclusions

In economics, utility is the function that drives value. Unfortunately, economic models of rational, utility-driven behavior tend to fail in unfamiliar settings and tend to ignore learning altogether. Such models, therefore, tend to be rather limited in their ability to say useful things about real-world informing. Only the most mechanical of informing systems functions with neither learning nor the unexpected.

Rather than abandon utility altogether, the present chapter has attempted to construct a model of utility that synthesizes findings on learning and motivation from a wide range of disciplines, including management, economics, cognitive science, neuroscience, and connectionism. The model, intended to be cognitively plausible rather than mathematically convenient, proposes that utility passes through a continuum of stages, starting with utility that arises from a set of relatively generic drives that are hardwired into all of us and ending with utility that is, essentially, hard-wired to progress in completing whatever task that the individual is focused on. The rough stages of this progress, as might be encountered for task performance in an informing system, are summarized in Table 3. Why we would need to understand these stages prior to applying utility to informing situations should be readily apparent; a utility model that fails to accommodate task unfamiliarity and learning processes would be sterile indeed for purposes of understanding the motivation to inform and be informed.

In addition to the obvious direct relevance of utility to informing, the chapter also can be viewed as a case study on the challenges presented by excessive specialization and, particularly, the creation of disciplinary silos that do not talk to each other (see Chapter 2). A principal source of the weaknesses in existing conceptions of utility is the concept's separate trajectory in many disciplines. In economics, it is called utility and has evolved so as to ensure the desired level of mathematical

Table 3: Utility sources for task performance

Source of Utility	Description
Task progress	Intrinsic utility derives from the process of completing the task. Because the task has become routine, the conscious satisfaction of individual task-related goals is no longer required. In this stage, neoclassical models of the utility of information are likely to be valid.
Task goals	Intrinsic utility derives from satisfying and progressing towards a series of specific goals that are presented as part of the task. These goals may serve to direct activities or act as targeted levels of achievement. In this stage, task-related utility is best predicted by the goal setting models so extensively documented in management and psychology. Inconsistencies in decision-making and biases will tend to lose impact in this region as goals become increasingly well established. As the task is repeated, specific goals and tradeoffs between goals become increasingly automated, ultimately leading to migration towards the task progress stage.
Generic drives and desires	Intrinsic utility derives from satisfying and progressing towards generic drives and desires that are present, to varying degrees, in all individuals. At this level, which is applicable mainly to highly unfamiliar and learning-oriented tasks, utility tends to be highly subject to framing issues and cognitive biases of the sort that economists and decision scientists have identified in experiments—often inconsistent with "rational" models of behavior. As task-specific goals are learned, the utility migrates towards the task goals stage.

tractability and suitability for policy analysis; in the decision sciences, a virtual cottage industry has developed around demonstrating utility's axiomatic inconsistencies but such analysis is mainly limited to lab settings involving tasks unfamiliar to subjects; in applied psychology utility corresponds to motivation and it has been particularly influential in explaining non-economic factors influencing choice but, once again, mainly done so in controlled lab settings; in education, it is also aligned with motivation, but its focus is specialized on learning situations and entirely ignores economic aspects; in evolutionary biology, it is called fitness and it is explained largely in terms of characteristics promoting survival. Because these disciplines do not regularly talk to each other, each has developed their own version of the concept that has strengths in the context of use, but also exhibits many weaknesses when considered outside of that context. An important role for a transdiscipline, such as the informing sciences, is to attempt to reconcile these separately evolved views into a more coherent whole.

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Chapter 9

Informing Resonance: Beyond Rigor and Relevance

T. Grandon Gill

Introduction

To understand what is information for a client, one must understand the client's task. To maximize the form, format, and schedule, one must understand not only the task, but also the client's psychology.

(Cohen, 1999)

When Eli Cohen proposed the informing sciences as a new transdiscipline, he made it clear that maximizing the "effectiveness" of the information provided to the client was integral to the definition of the field. Such effectiveness, however, cannot be achieved solely though achieving *quality* on the part of the sender and *usefulness* with respect to the task being performed by the client. As stated in the opening quote, if informing is to have a meaningful impact on the client, an understanding of the psychological characteristics of that client will be critical.

Chapter 3 of this book echoes this theme, arguing that the traditional dichotomy of *rigor* (research quality from a discipline's perspective) versus *relevance* (potential utility of the research to client activities) was misleading. A third characteristic, *resonance*—reflecting the ability of the research message to move through available channels to the client and, subsequently, to impact that client's mental models—is also a prerequisite of effective informing. If, for example, research results are presented in a format that makes them nearly incomprehensible to practitioner clients (e.g., emphasizing descriptions of research methodology and employing advanced statistical techniques for purposes of significance testing) and are disseminated through channels that do not reach these clients (e.g., academic journals), the quality of the research and its potential usefulness will not matter. The client will likely remain uniformed.

Achieving resonance is no easy task. To begin with, it often involves two distinct processes, that of sender-to-client informing and, subsequently, that of client-to-client informing (e.g., word-of-mouth). For example, research into the diffusion of innovations finds that while the sender-to-client process can be highly effective in informing "innovator" clients during the early stages of diffusion, later stages of diffusion nearly always depend upon client-to-client informing (Rogers, 2003). Thus, understanding both of these processes is likely to be a prerequisite for effective informing.

The present paper focuses primarily on achieving resonance in individual clients, leaving its discussion of client-to-client processes until the final section. We begin with a historical case study that illustrates how informing can fail despite both a rigorously tested message and an idea that was clearly useful. We then examine the existing research published in the informing science field, noting the relatively small emphasis that has been placed upon investigating sender-to-client resonance. A survey of the broad array of potentially relevant findings from a wide range of disciplines—including contributions from psychology, education, anthropology, the cognitive sciences, and management—then follows. From this, insights into what types of messages will and will not resonate with clients are distilled. Finally, these findings are synthesized into a general model of single client resonance. In the final section, we then consider how the filters that impact single client resonance will, necessarily, create a role for client-to-client informing processes. Models of these processes are then introduced, followed by a brief conclusion.

A Case Study: Morison's Gunfire at Sea

Within the innovation literature, a widely cited example that highlights the challenges of achieving acceptance of an idea is presented in Elting Morison's *Man, Machines and Modern Times* (1966). The case study, summarized below, describes the obstacles experienced in attempting to convince naval authorities of the validity of a new way to fire the guns installed on U.S. naval vessels.

By way of context, achieving accuracy when firing shipboard guns has always been more problematic than achieving comparable accuracy with land-based artillery. The main source of the difficulty is the rolling of the ship, which means that the angle of the gun's barrel is always changing. As a consequence, as late as at the turn of the 20th century, individual gunners had to develop personalized approaches to compensating for the movement. Morison (1966, p. 21) describes the process as follows:

> First of all, the rapidity of fire was controlled by the rolling period of the ship. Pointers [gunners] had to wait for the one moment in the roll when the sites were brought on the target. Notice also this: There is in every pointer what is called a "firing interval"—that is a time lag between his impulse to fire the gun and the translation of this impulse into the act of pressing the firing button. A pointer, because of this reaction time, could not wait to fire the gun until the exact moment when the roll of the ship brought the sights into the target; he had to will to fire a little before, while the sites were off the target. Since the firing interval was an individual matter, varying obviously from man to man, each pointer had to estimate from long practice his own interval, and compensate for it accordingly.

Another factor impacting accuracy involved the gun sights. Although telescopic sights were sometimes provided to enlarge the target, they were attached to the gun barrel and "recoiling with the barrel, jammed back against the unwary pointer's eye" (Morrison, 1966, p. 21). Thus, while useful in estimating target range, they were virtually never used during the actual firing process.

In 1898, an English officer—Admiral Percy Scott—developed an alternative approach to firing guns that involved continuous aiming. This approach involved three relatively minor changes to the physical equipment—changing the gear ratio on the guns, mounting a simulated target on the mouth of the gun, and changing the telescopic mountings so they did not recoil into the pointer's eye upon firing—and a major change to firing procedures: having the pointer continuously adjust the gun elevation so that it was always on the target. The results of this innovation were astounding:

> In 1899 five ships of the North Atlantic Squadron fired five minutes each at a lightship hulk at the conventional 1600 yards. After twenty-five minutes of banging away, two hits had been made on the sails of the elderly vessel. Six years later one naval gunner made fifteen hits in one minute at a target 77 by 25 feet

> at the same range—1600 yards; half of them hit in a bull's-eye 50 inches square (Morison, 1966, p. 22).

In 1900, while serving in China, Scott met a junior U.S. naval officer, William S. Sims, who eagerly embraced the new approach and made the modifications necessary to institute the technique on his own ship. After a few months of practice, he demonstrated astounding improvements in accuracy, after which he began to communicate his findings with his U.S. Navy superiors in a series of 13 reports. Described by Morison (p. 22):

> Over a period of two years, he reiterated three principal points: first, he continually cited records established by Scott's ships, the *Scylla* and the *Terrible*, and supported these with accumulating data from his own tests on an American ship; second, he described the mechanisms used and the training procedures instituted by Scott and himself to obtain these records; third, he explained that our own mechanisms were not generally adequate without modification to meet the demands of continuous-aim firing.

From an informing perspective, these messages clearly demonstrated two things. First, the quality of the information was rigorously supported by multiple sources of the evidence. Second, the usefulness of the approach to the client (i.e., the U.S. Navy) was shown through outcome-based measures. Thus, the conditions of both rigor and relevance were clearly met. What transpired thereafter, however, illustrates how quality and usefulness may not be sufficient to ensure that effective informing takes place.

Morison (1966) described the Navy's reaction as taking place in three stages. During the first stage, Sims's reports were simply ignored. Indeed, after being filed away they were largely consumed by cockroaches—the 19th century analog to media failure. From an informing standpoint, this represents failure to attend to the channel. This failure of informing appears to have an underlying source that is mainly motivational in character: the individuals who received the correspondence had no particular interest in their contents.

After his initial efforts failed, Sims adopted a more strident tone in his reports and also began circulating them to other naval officers in the fleet. Described by Morison (p. 28-29):

> Aware as a result that Sims's gunnery claims were being circulated and talked about, the men in Washington were then stirred to action. They responded, notably through the Chief of the Bureau of Naval Ordnance, who had general charge of the equipment used in gunnery practice, as follows: (1) our equipment was in general as good as the British; (2) since our equipment was as good, the trouble must be with the men, but gun pointers and the training of gun pointers were the responsibility of the officers on the ships; and most significant (3) continuous-aim firing was impossible.

The third of these was based on experiments, conducted in Washington Navy Yard, where it was found that five men could not operate the gears fast enough to achieve the rate of changes in the gun barrel angle that were required to support continuous aiming. In his rebuttal to the last point, Sims pointed out that the fixed platform test was invalid; instead, the rolling of the ship provided momentum to the gun barrel that actually made continuous aiming much easier.

From an informing standpoint, the three elements of the response from Washington clearly illustrate a practical challenge to achieving resonance: the existence of prior mental models. The client belief that U.S. equipment could not be inferior to that used by the British made accepting Sims's premise much more difficult. The belief that the accurate gunnery could only be achieved through training and that the task was a ship's responsibility—rather than that of the bureau—caused the client to question the relevance of the information. Finally, knowledge of the existing test caused the client to question the veracity of the information. Conceptually, then, prior mental models distorted the information during the communications process. As a consequence, the client's interpretation of the message did not match the sender's intent.

Returning to the narrative, Sims's increasingly agitated tone ultimately led to the third stage: "name-calling". Described by Morison (p. 31):

> He was told in official endorsements on his reports that there were others quite as sincere and loyal as he and far less difficult; he was dismissed as a crackbrained egotist; he was called a deliberate falsifier of evidence.

In this stage, the principal obstacle to informing was less a matter of distortion resulting from prior mental models than of outright refusal to change existing models. There was no longer any desire to believe Sims; indeed the clients had an active interest in disbelieving him. Morison (1966, p. 36) further argues that a secondary but critical further source of resistance came from the implications that would necessarily result from the acceptance of the idea. Gunnery had always been perceived as an art rather than a science. As such, it has occupied a relatively low status position in the increasingly technological Navy. Sims's innovation would transform the nature of the task—increasing the status of gunnery with respect to other shipboard activities (such as ship handling) and prospects for promotion. In the context of an organization that had only recently made the transition from sail to steam and was still adjusting to its aftereffects, the motivation to accept the information that Sims was communicating was low indeed. This demonstrates that, in the informing context, failure to consider or accommodate the client's intrinsic motivation can lead to a complete breakdown of the informing process. When such motivational conflicts are present, message distortion is no longer the issue. The complete unwillingness of the client to modify existing mental models is the source of the problem. The described nature of the communication also indicates the important role that emotions can play in the informing context.

Ultimately, Sims broke the informing deadlock by writing directly to Theodore Roosevelt, then President of the United States. Roosevelt brought Sims back to the U.S. and assigned him to the post "inspector of Target Practice", where he continued for six years. During that period, his innovation diffused throughout the Navy and he was ultimately acclaimed as "the man who taught us how to shoot", eventually making Admiral and getting a warship named after him (USS William S Sims, DE/FF-1059). This would be an example of a case where intrinsic motivation failed using a particular channel. As a result, an alternative channel was needed and considerable extrinsic motivational force had to be applied.

In summarizing this case from an informing standpoint, we can see three key elements of what we'll refer to as resonance. Even after rigor and relevance has been established, the content needs to be *internalized and made available for later recall*, something that did not happen for the early letters owing to lack of motivation on the part of the client. The amount of *distortion* between the sender's intent and the client's interpretation needs to be minimized, a failure evident in the first response received by Sims; a consequence of initial differences between sender and client mental models. Finally, the client must be *willing to restructure his or her mental models* to incorporate the content, another motivational issue that is also subject to significant emotional forces. If any of these prerequisites of resonance are not met, the informing can fail.

Resonance in the Informing Sciences Literature

A principal objective of the current paper is to encourage research into the resonance phenomenon within the informing sciences. A useful starting point in reviewing resonance-related research, therefore, is to consider what findings already exist within the informing sciences literature. In this context, it makes sense to specifically limit our review to articles published within the Informing Sciences Institute family of publications, saving our broader review of the concept for the later sections in which the model is developed.

As noted in the introduction, Chapter 3 proposes that resonance should be a research agenda for the informing science. My co-author and I suggest the term is needed to augment the concepts of rigor and relevance in order to describe "the ability of … research to bridge the divide between sender and client". We further proposed that it consists of two parts: 1) the ability to resonate within a single client, and 2) the ability to promote subsequent client-to-client informing.

In a study of the Australian film industry (Alony, Whymark, & Jones, 2007), numerous resonance-related phenomena were observed to facilitate the transfer of tacit information among participants. Among these were participant diversity, strength of ties, cohesion and trust. Several of these appear to relate to credibility, also an important issue raised in the case study. Gackowski (2006) points out the multidimensional nature of credibility, further arguing that it is a critical component of the information quality construct.

One research study that particularly relates to resonance issues examines how client biases act as filters on information received (Jamieson & Hyland, 2006). As shown in Figure 1, four different filters are proposed:

1. information biases,
2. cognitive biases,

3. risk biases, and
4. uncertainty biases.

Information biases reflect mechanisms that modify incoming information to align it with existing client preferences, usually applied at an unconscious level. Cognitive biases are employed to simplify decision making so as to keep it within the limits of the client's bounded processing resources. Risk and uncertainty biases derive from client attitudes towards risk and uncertainty, respectively. Because these filters, particularly the first two, can serve to block information altogether, they can act as severe impediments to resonance.

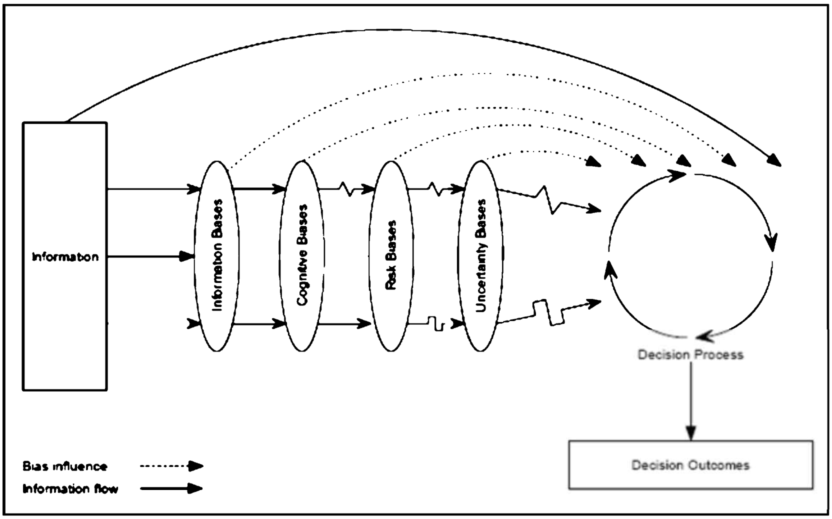

Figure 1: Client Information Filters (from Jamieson & Hyland, 2006)

Chapter 7 synthesizes the literature on task complexity, noting that several existing task complexity definitions relate task complexity to motivational characteristics and to the nature of the task performer's mental models (i.e., problem space). It therefore follows that a strong interaction between task complexity and resonance can be expected.

The specific impact of structural complexity on informing (T. G. Gill, 2008a) has been examined. The model of task structure that was proposed uses a problem space—consisting of a state space (schemata), operator space (operators and control knowledge), and a goal space (consisting of goals and a goal fitness operator)—and examines how the qualitative nature of task knowledge changes with accumulating expertise. Within each space, a top level (Level 4) consists entirely of general purpose knowledge. Task specific knowledge exists at Levels 1 through 3, with Level 3 consisting of high level concepts, theory, and principles at one extreme, and Level 1 being highly compiled knowledge chunks and automated operators that do not require conscious attention at the other extreme. As tasks are repeatedly performed, task knowledge gradually transforms from higher levels to lower levels through a process known as knowledge compilation (Neves & Anderson, 1981). The model predicts that informing between practitioners and academics will tend to be highly problematic. The reason given is that a practitioner problem space tends to be dominated by Level 1 knowledge, brought about by frequent repetitions of a relatively limited number of task situations (task cases). The academic problem space, on the other hand, tends to be dominated by Level 2 knowledge; studying a task will not produce the same type of knowledge compilation as repeatedly performing it, but such conceptual knowledge gained from systematic study is likely to be applicable to a broader set of task cases. This difference is illustrated in Figure 2.

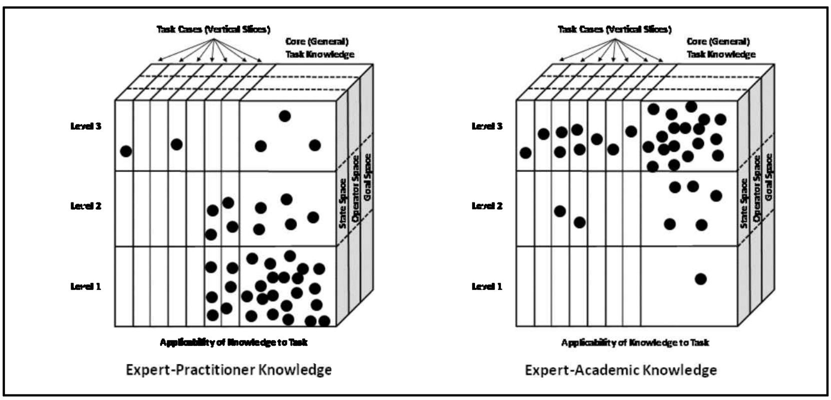

Figure 2: Practitioner versus Expert Knowledge (from T. G. Gill, 2008a), showing how practitioner task knowledge tends to be much more highly compiled than academic knowledge.

Informing systems design is another area where resonance-related concepts appear. A recent research stream applies philosophical perspectives, drawn from schools such as hermeneutics and phenomenology, to the informing system design process. Rather than perceiving informing as a straightforward process by which information is transferred, these schools emphasize parallel processes of knowledge acquisition and reflection/sense-making that continually interact, sometimes visualized using the metaphor of a double helix (see Chapter 14 and Nissen, 2007). In such systems, users not only become involved in system design, but that involvement becomes an integral facet of the community in which they exist (Pang & Shauder, 2007). Thus, the client-to-client element of resonance is emphasized. The objectives of information systems design processes also differ under such a model, emphasizing paying greater attention to the user's existing mental models and supporting user patterns of action (a.k.a., praxis) as opposed to strictly focusing on the usability of the system (Whittaker, 2007). What these models suggest is that in informing activities and in designing informing systems, a narrow-minded focus on the task at hand—one that ignores existing practices and the community in which the task is being performed—is unlikely to lead to effective informing. Once again, the conclusion asserts that meeting the prerequisites of rigor and relevance cannot ensure that resonance will be achieved.

Single Client Resonance Model

In the naval gunfire case study, it was pointed out that there were two types of moderators (in the case example, barriers) to informing: issues relating to the client's existing mental models and issues relating to the client's motivation. In considering how informing impacts the client, we synthesize the findings from three sources: the gunnery case presented earlier, the structural complexity model (T. G. Gill, 2008a) and the bias filter model (Jamieson & Hyland, 2006). In performing this synthesis, we make three assumptions:

1. Because the problem space levels and forms of learning can be quite different in character, the nature of the filters that impact resonance may differ significantly. We therefore consider each level separately.
2. The bias in the filter model can work in three ways: it can change information passing through the channel (including adding information not originally conveyed), it can inhibit specific information flowing through the channel, or it can amplify information disproportionately to competing information. All three filter actions produce distortion.

3. Unless otherwise stated, we assume that the sender's intent is to convey information as accurately possible to the client. From time to time, however, we also recognize that the distortion created by these filters may be intended by the sender, used as a tool for manipulating the client.

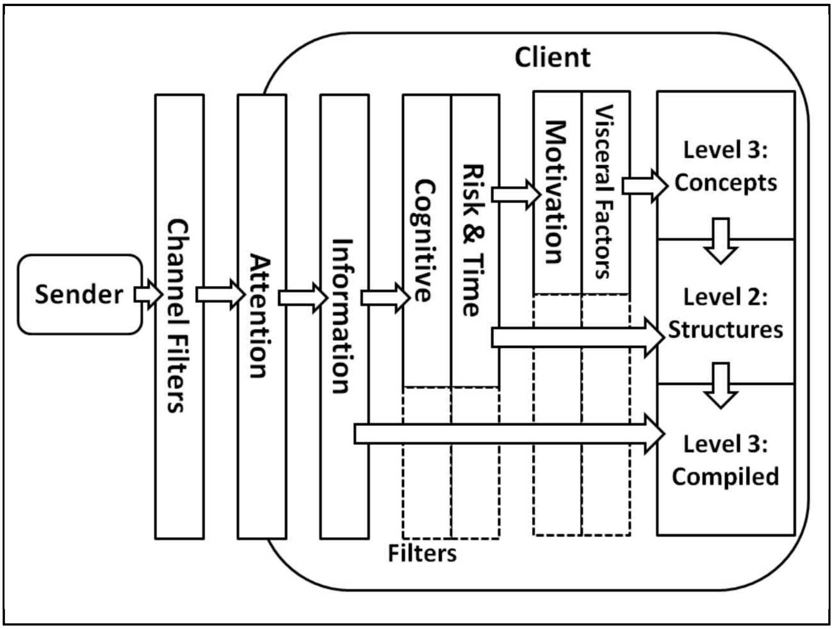

Figure 3: Client Resonance Model

To achieve a consistent synthesis, as illustrated in Figure 3, we start with the original bias filter model (Jamieson & Hyland, 2006) and make the following modifications:

- *We add an attention filter at the input to the client.* As suggested by the naval gunnery case, the initiation of informing by the sender does not guarantee processing by the client—the message may just be ignored. This filter, it is assumed, will depend heavily on motivational and visceral elements of the informing situation.
- *We treat uncertainty as part of the structural model, rather than as an explicit filter.* The structural complexity model itself incorporates the notion of uncertainty directly—both through its state,

operator and goal space levels and through uncertainty levels characterized for each state.

- *The "risk biases" filter is generalized as the "risk and time preference" filter.* This reflects the fact that attitudes towards risk and time often lead to similar effects and anomalies (see Chapter 7). It is also consistent with some biological evidence that delayed and uncertain outcomes employ a great deal of common circuitry in the brain (Politser, 2008, p. 54). It is shown as adjacent to the cognitive filter because there is no particular reason for assuming one form of filtering will occur prior to the other.
- *A motivation filter is added.* This filter specifically addresses the aspects of the motivational context of the informing that are directly related (i.e., intrinsic) to the task that is the object of the informing.
- *A visceral factors filter is added.* This filter addresses motivational issues that extend beyond the task and, more generally, to the overall impact in informing of visceral factors, which include drives (e.g., hunger, thirst), moods, emotions, and pain. It is placed adjacent to the motivation filter because, once again, no particular ordering can be assumed with respect to motivational versus emotional filtering.

In addition to the changes within the client system, we explicitly recognize filters exist that are best viewed as being a property of the informing channel. It should be self-evident that channel capabilities—media richness (Daft, Lengel, & Trevino, 1987), interactivity, time delays, capacity limitations—can exert a powerful influence on the nature of informing. Suppose, for example, you were a sender whose goal was to inform the client about the emotional impact of the Mona Lisa. If you were employing a broadcast text channel—such as a list server—there would be significant limitations on what types of information you could convey. To get around that you might relate studies regarding the nature of that impact, describe techniques employed by da Vinci to achieve such impact, and you might even describe its personal impact on you. The nature of the informing process would change dramatically, however, were a richer channel available. You might choose to present a high-resolution picture of the work. You might show video clips of tourists being affected as they viewed the painting at the Louvre. You might also cite the previously studies as well, of course. Thus, the choice of channel—which may be a decision of the client, the sender, or a mutual decision—can exert a powerful influence on the nature of the informing message. While channel selection is not the central focus of the present paper, which is specifically directed towards modeling client-side processes, it will need to be mentioned from time to time, since channel choice can impact other aspects of the informing process. Indeed, it is probably a mistake to get too comfortable treating the behavior of any element of an informing system as being independent from the remaining elements. Informing systems tend to exhibit many attributes that imply non-decomposability, otherwise referred to as rugged fitness landscapes (see Chapter 12 for a discussion of rugged fitness landscapes). In such systems, behaviors observed in isolated components often change substantially when observed in the context of the complete system.

We now explore the behavior of the single client resonance model. We do so first by considering how the filters are impacted by existing mental models. Next, we consider how intrinsic motivation—that is, motivation that is specifically related to the task around which informing is taking place—influences resonance. Finally, we consider the range of impacts on resonance that may be expected in the presence of visceral factors, with a particular emphasis on the role of emotions.

Resonance and Mental Models

In considering how resonance is impacted by pre-existing client knowledge, it is useful to specify what is meant by the term "mental model". For the purposes of the present paper, a relatively simple schema-based model will suffice—since the majority of research relating to cognitive issues surrounding learning generally employs a similar perspective. In this model, knowledge is represented by schemata which are, in essence, objects possessing attributes (that may themselves be schemata). Over time, simple schemata may combine into more complex schemata through a process referred to as chunking (Miller, 1967), thereby allowing limitations on the number of available objects in working memory to be overcome. In such a model, three qualitatively different forms of learning are implicit (Rumelhart & Norman, 1981, p. 335):

1. *Accretion:* the process of incorporating new information into existing schemata.

2. *Tuning or schema evolution:* The gradual process of refining existing schemata.
3. *Restructuring or schema creation:* The process by which new schemata are created. It may also apply to situations where existing schema are radically reconfigured, as would be the case where an existing mental model is replaced by a new one.

These forms also map well into a structural complexity model (T. G. Gill, 2008a), with restructuring being the most likely means for transforming conceptual schemata (Level 3), and accretion leading to incorporating information into existing compiled schemata (Level 1).

Accretion

The process of accretion has been described as "the most common and least profound sort of learning" (Rumelhart & Norman, 1981, p. 336). The accretion involves bringing information into existing schemata, roughly comparable to filling in values on an incomplete form. Because the cognitive demands imposed by accretion-based processes are likely to be limited—task knowledge at the accretion level tends to be highly compiled—the most likely barrier to informing is the distortion of incoming information specifically associated with the information biases filter.

Many of the information biases that have been proposed appear to have a strong motivational character. For example, desirability bias, optimism, outcome bias, and wishful thinking (Russo, Meloy, & Medvec, 1998) all have their origins in what the informing client wants to be true, rather than what necessarily is true. These will be discussed when we later consider the subject of resonance and motivation. There are, however, equally pervasive barriers that distort information, often unconsciously, based upon the client's existing task knowledge. Examples of these are now considered.

Judgment by Representativeness (e.g., Teigen, 2004). Representativeness is a mental shortcut that we use to avoid the need for extensive data gathering. It involves acquiring a small amount of information that is then mapped to some pre-existing schemata—a representative case—after which we base our actions and conclusions based upon the representative case. Such a phenomenon is likely to be most pronounced where task expertise is high, since the availability of representative examples will tend to be greater. Consider the following example:

> You observe a person on the pavement who appears to be talking to himself. He is alone but smiling and gesturing. You decide that he is probably crazy. (Teigen, 2004, p. 165)

This example also illustrates the dangers inherent in representativeness. If an additional piece of information is provided or observed—that the individual was wearing a cellular phone ear piece—we might reach a radically different conclusion. Indeed, viewed in the context of a later time period (e.g., 2008 vs. 2004), many of us might have jumped to the cellular phone conclusion initially—since most of us have probably already observed such behavior.

The danger inherent in the representativeness bias is its inhibiting effect on informing; it tempts the client to end the informing process even though additional information gathering is warranted prior to drawing a rigorous conclusion. Indeed, representative issues first emerged in the context of individuals drawing statistically invalid conclusions from a small set of observations (e.g., Tversky & Kahneman, 1982b).

Availability (e.g., Reber, 2004). Availability is characterized as making decisions based upon that information that is readily available to the task performer. Since availability, in turn, can be influenced by salience (i.e., how vivid the information is) and recency (Tversky & Kahneman, 1982a), judgments that are based on availability can be significantly influenced by factors that are outside of the domain of the task. The availability effect can work in two ways. First, it can occur in conjunction with representativeness; readily available examples become the most likely to be accessed as being representative. Second, it can lead to a pronounced *recency effect*—also known as the serial position effect (Frensch, 1994)—in which the client recall for information acquired at the beginning and end of the informing process is amplified in comparison with that information transferred in the middle of the process.

Confirmation Bias (e.g., Oswald & Grosjean, 2004). Clients tend to search for and interpret information that confirms their existing schemata. As a consequence, as a sender provides information that is similar to, but slightly different from, the client's own mental models, the client is likely to interpret it as being entirely consistent with those models. This bias also serves to amplify the impact of information consistent with the clients existing models.

Collectively, these representativeness, availability, and confirmation effects directly impact the validity of the changes made to the client's internal mental models during the informing process. Perhaps more importantly, they may prevent the client from recognizing situations where existing schemata are inadequate. As a result, they may inhibit schema evolution or restructuring in contexts where the nature of the task warrants these higher levels of informing.

Tuning and Schema Evolution

Schemata tuning and evolution is the orderly process by which new and revised representations are gradually added to the client's problem space. Such a process is likely to place considerably more cognitive demands on the client and, as a consequence, filters that reduce cognitive load are likely to play a larger role. Thus, we need to consider both cognitive and information filters at this level.

As a starting point, we should recognize that filters playing a role in accretion are also likely to play a role in schemata evolution. Indeed, it has been proposed that many information and cognitive heuristics—originally conceived of as biases and illusions—actually work quite well in those situations where there is a genuine need to economize on processing (e.g., see Table 4.1, Gigerenzer, 2004, p. 66). These filters can, however, inhibit the client's recognition of the need for new schemata, as previously noted. Filters that seem particularly relevant to the tuning and evolution level are now considered.

Recognition Heuristic (Gigerenzer, 2004). Information leading to schema evolution is likely to include a mixture of familiar and unfamiliar content (otherwise it could be handled through accretion). The recognition heuristic posits that when the two forms of information are comingled, the recognized information will play a much greater role in subsequent decision-making. An interesting demonstration of this heuristic occurred when separate groups of U.S. and German students were asked the question "Which city has more inhabitants: San Diego or San Antonio." Most U.S. students got the answer correct. What was more remarkable was the performance of the German students:

> …most Germans know little about San Diego, and many have not even heard of San Antonio… Despite a considerable lack

> of knowledge, 100 percent of the Germans answered the question correctly. How can people who know less about a subject nevertheless make more correct inferences? The answer is that the Germans used a fast and frugal heuristic: the recognition heuristic: If you recognize the name of one city but not the other, then infer that the recognized city has the larger population. The Americans could not use that heuristic because they had heard of both cities… (Gigerenzer, 2004, p. 68)

The obvious challenge that such a heuristic presents to the sender is in dealing with circumstances where the nature of the information that will be recognized by the client is unknown. In such situations, recognition could play a large role in client interpretation that is entirely outside of the sender's intent. In effect, an unintended recognition "adds" information to the message—in the form of the attributes of the recognized entity—that was not provided by the sender and may lead to distortion of meaning.

Choice strategies (e.g., Payne, Bettman & Johnson, 1993). A wide range of strategies specifically designed to reduce the cognitive load of choice problems has been observed or proposed. In such problems, clients are presented with a set of alternatives, each of which has attributes that impact an alternative's attractiveness. Some of the most important choice heuristics (adapted from the list provided by Payne et al., 1993, p. 25-29) include:

- *Equal weight heuristic* (Einhorn & Hogarth, 1975): Alternatives are compared across all relevant attributes, with each attribute being given an equal weight.
- *Satisficing* (Simon, 1955): Alternatives are considered until a pre-determined or adaptively determined cut point for fitness is reached.
- *Lexicographic heuristic* (Tversky, 1969): Alternatives are compared across the most important attribute and only those at the top are retained. Then the second most important attribute is considered and the process continues until only one alternative remains.
- *Elimination by aspects* (Tversky, 1972): Similar to lexicographic comparison, alternatives are compared across the most

important attribute and only those meeting a desired cut point are retained. Then the second most important attribute is considered and the process continues until only one alternative remains.

- *Majority of confirming dimensions* (Russo & Dosher, 1983): Alternatives are pair-wise compared attribute by attribute and the choice with the greatest number of winners is retained for comparison with the next alternative.
- *Frequency of good and bad features* (Alba & Marmorstein, 1987): The positive and negative attributes of each alternative are counted. Choice can then be made based on the fewest number of bad features or the largest number of good features.

If a client is using such heuristics, then a number of sender-related decisions, such as the order in which alternatives are presented (particularly for satisficing) and the nature of information communicated about each option can exert a strong—and possibly unintended—impact on client task performance. For example, the sender's choice to emphasize quantitative or qualitative information may exert a significant influence on these heuristics and on the ultimate decision (Brindle, 1999). Here, once again, the nature of the channel employed may further impact choice through the informing process. Consider, for example, how the role of the real estate agent (sender) has changed in the real estate industry as the richness of the Internet-based real estate informing channels has grown and how the client's (buyer's) activities in the choice process has changed as a result.

Risk and Time Preferences. Risk and time preferences can interfere with informing when the sender's perception of or attitudes towards risk and timing differ from those of the client. For example, an alternative that appears sensible to risk-neutral, return-maximizing sender, such as a consultant, could be perceived quite differently and rejected out of hand by a risk-averse client. This could prove to be a significant barrier to informing across levels within an organization since the attitudes towards risk may systematically vary across the levels of an organization, with higher levels generally exhibiting greater risk tolerance (March & Shapira, 1987). As a consequence, the communication of risky strategies devised by top management may be attenuated during the process of informing middle and lower management. A similar case can be made for time horizons that differ between sender and client. Informing an employee about the importance of acting in accordance with an organization's long term strategic goals may not be terribly effective if the employee is already planning to leave the organization and return to school.

Restructuring or Schema Creation

Where informing requires the creation of new knowledge or major restructuring of existing knowledge, the potential for informing filters and motivation effects to influence the client is at its peak. Some of the message distortion that can occur as a result of cognitive filters is now considered.

Learning by analogy (e.g., Rumelhart & Norman, 1981). Where information being conveyed requires new knowledge structures, existing knowledge structures from different domains are often enlisted as part of the learning process. This is process is referred to as learning by analogy. This powerful technique allows us to leverage expertise from one domain and apply it to another. Unfortunately, our ability to recognize appropriate analogies is imperfect. This assertion is supported by research in which isomorphic problems were created specifically so as to allow subjects to take knowledge from one situation and apply it to another. For example, in an experiment where various tasks were created so as to be identical to the "Tower of Hanoi" puzzle (which subjects had previously learned to solve) the results were disappointing:

> In fact, any of the problems could have been solved by mapping it into the Tower of Hanoi problem and then solving the latter. No subject did this, and only two or three even thought of trying or noticed the analogy. The problems, then, were identical in formal structure, but different in their "cover stories". (Simon & Hayes, 1976, p. 478)

The problem that analogy creates from the sender's perspective is that the client's base of expertise outside of the task at hand will almost certainly be unknown. As a result, given the inconsistency of the analogy process, it may be very difficult to predict *what* analogy the client will use in constructing his or her new schemata. Thus, distortion between sender intent and client interpretation can easily arise.

Framing (e.g., Soman, 2004). A framing effect occurs where the particular presentation of a problem has a significant impact on the client's preferences or solutions. A common way to demonstrate framing issues is to take advantage of the asymmetry between gain and losses observed for most individuals, with greater sensitivity to losses than to gains as discussed in Chapter 7. Thus, a problem presented as an initial state followed by an opportunity to gain is more attractive than an initial state followed by a risk of losing. Consider, the following example (presented in Chapter 7, where it was adapted directly from Tversky & Kahneman, 1988, p. 173-174):

First choice problem:

> Assume yourself richer by $300 than you are today. You have to choose between:
>
> A. A sure gain of $100
>
> B. 50% chance to gain $200 and 50% to gain nothing

Second choice problem:

> Assume yourself richer by $500 than you are today. You have to choose between:
>
> A. A sure loss of $100
>
> B. 50% chance to lose nothing, 50% to lose $200

The actual results of this experiment were that most (72%) chose A in the first problem, while most (64%) chose B in the second. This distinct preference is purely a result of framing since options A and B across both choice problems lead to precisely the same outcomes: a $400 gain for option A, a 50-50 distribution between $300 and $500 for option B.

The structural complexity model proposes that cognitive framing (along with other effects such as anchoring) results from the use of generic goals to address unfamiliar problems (see Chapter 7). As a consequence, framing-related distortions that occur in informing relationships are likely to be most commonly observed where restructuring and schema creation are involved. Once an individual recognizes the likelihood of framing occurring, it can be compensated for. Such recognition should come with experience, although this may be better described as a hypothesis than an assertion.

Anchoring (e.g., Mussweiler, Englich, & Strack, 2004). Anchoring effects are similar to framing effects; they occur when some initial value or alternative encountered in the task—often relatively arbitrary in nature—impacts subsequent decision making. These effects can influence decisions in two ways: 1) they may present the sender a means of manipulating client preferences and decision making or 2) they may lead the sender to influence client preferences and decision-making inadvertently.

Anchoring frequently occurs as a consequence of detecting favorable comparisons and similar options among choices. Common effects involving three or more options include (Usher & McClelland, 2004):

- *Attraction:* Where three options are presented to a decision-maker and two are similar, with one clearly dominating the other, decision-maker preference tends to skew towards the dominant option in the pair, regardless of the characteristics of the third.
- *Similarity:* Where three options are presented and two are similar (with neither dominating), decision-maker preference skews towards the third, non-similar option.
- *Compromise:* Where three options are presented and one option could be viewed as a compromise between the other two, that option is disproportionately selected.

Illustrative examples of these types of effects abound in consumer marketing. For example, the "decoy effect", a variation of attraction, involves using one product model to anchor perceptions of another model. Consider the following example:

> When Williams-Sonoma first introduced a home "bread bakery" machine (for $275), most consumers were not interested. What was a home bread-making machine anyway? … Flustered by poor sales, the manufacturer of the bread machine brought in a marketing research firm, which suggested a fix: introduce an additional model of the bread maker, one that was not only larger but priced about 50 percent higher than the initial machine.
>
> Now sales began to rise… [Consumers] could say, "Well, I don't know much about bread makers, but I do know that if I were to buy one, I'd rather have the smaller one for less

> money." And that's when bread makers began to fly off the shelves. (Ariely, 2008, p. 14-15)

In this example, the anchoring effect was specifically used to the sender's advantage. It could, in fact, be construed as a manipulation of the client's cognitive system.

Resonance and Intrinsic Motivation

Whereas pure mental model effects most likely result in distortion of information transferred during the informing process, motivational effects can lead to failure to attend to a channel or to outright rejection of the message being transmitted. In this section, we consider the potential of intrinsic motivation—that is, motivation arising from the task itself—to influence informing. Visceral influences that fall outside of the task are addressed later, in the next section.

Utility, Motivation, and Informing

When economists and decision scientists attempt to assess the value of informing, the first concepts they typically introduce are uncertainty and utility (e.g., Hirshleifer & Riley, 1992). The conceptual model then presented is that informing reduces uncertainty, which provides value to the client through increasing utility. Utility, in turn, is a measure of satisfaction that economists use to explain choice behavior. When presented with a series of alternatives, the rational decision maker chooses the alternative that maximizes utility. Because economists are principally concerned with economic returns, utility is generally viewed to be treated as a function of monetary returns, adjusted for risk, timing, and diminishing returns (see Chapter 7).

While the economic utility model serves economists well enough, it is filled with inconsistencies when investigated from a psychological perspective. Human decision makers do not generally exhibit rationality of the sort that is axiomatic in utility-based models. Indeed, many of the issues discussed in the present paper—such as framing, anchoring, and satisficing—lead experimental subjects to exhibit preferences inconsistent with even the most plausible axioms, such as indifference between alternatives leading to identical outcomes.

In Chapter 7, a utility model has recently been proposed that is based upon more plausible psychological principles. This model is grounded in the large management goal setting literature concluding that individual motivation arises from the pursuit and satisfaction of individual goals (Bandura, 1991). Motivation is closely related to utility, since we are most motivated to take the action that leads to the highest utility. It therefore follows that—in the single-client informing model—the type of utility that we should be concerned with maximizing in informing relationships is going to be heavily driven by the client's goals. These goals may or may not be economic in nature.

Naturally, economic goals can play an important role in informing. But humans have many other goals that may be of equal or greater importance. Performance goals represent the individual's intrinsic drive towards exemplary performance on a given task independent of monetary rewards. Mastery goals represent the individual's desire to improve his or her knowledge. Both types of goals are common in informing settings, such as universities (Elliot & Harackiewicz, 1996). Individuals are also motivated by the desire to achieve control over activities (Gilbert, 2007; Thompson, 2004). Finally, social and altruistic goals (Simon, 1992) may play an important role in motivation. To ignore the role played by non-monetary client and sender goals in the informing process is to ignore one of the key factors that can derail informing. As illustrated in the naval gunnery case study, once the client's motivation to be informed is lost, the entire process can collapse and alternative channels will need to be found.

We now consider some specific examples of motivation-based issues that can impact informing. As also illustrated by the naval gunnery case, these motivational issues tend to exert an impact in two ways: by affecting the client's willingness to attend to the channel (attention filter) and by affecting the client's willingness to alter existing mental models to accommodate the new information being received (motivation and visceral filters). Such motivation, however, will derive from two separate sources: factors *intrinsic* to the informing-related task and factors *extrinsic* to that task (to be covered in the next section which considers visceral factors, as previously noted). As an organizing framework for the intrinsic factors, we'll use the three categories of task-related intrinsic motivation identified in a study of expert systems (T. G. Gill, 1996): *performance*, *arousal*, and *control*.

Performance, Mastery, and Abandoned Expertise

The first category of intrinsic motivation to be examined relates to performance. From an informing perspective, it can impact both client willingness to attend to the channel and willingness to change existing mental models.

Overconfidence (e.g., Hoffrage, 2004). Individuals, including experts, tend to be overconfident in their own knowledge. A natural consequence of this is inhibiting information flow; a client may terminate or cease attending to an informing process before all useful information has been transferred.

Conceptually, the structural complexity model would expect overconfidence to be most pronounced at the knowledge structure level, rather than the concept level. At the higher levels of structural complexity (Levels 3 & 4), client goals will tend to form a complex, multi-peaked fitness space (T. G. Gill, 2008a). In such an environment, excessive confidence should be less likely to develop. As the client acquires expertise, moving down to Level 2, specialization upon specific, well-defined goal peaks will tend to occur. That will lead to both substantially improved task performance and a tendency to lose sight of other peaks, referred to as the Law of Limited Visibility (T. G. Gill, 2008a) and also discussed in the context of goal-setting theory (Ordonez, Schweitzer, Galinsky, and Bazerman, 2009). As a result, the client's new—more expert—perception of the task being performed is reinforced. Such an evolution will lead to increased, and perhaps excessive, confidence.

A number of other observed phenomena are consistent with the more narrow view of the task that comes with practitioner expertise. One example is the *escalating commitment effect* (Jamieson & Hyland, 2006), where a promising alternative is given increasing amounts of attention until the point at which no other alternatives are being considered. Another is the *single outcome calculation* (Jamieson & Hyland, 2006), where a widely shared criterion is used to create a consensus for a particular decision without giving full consideration to other alternatives. Both of these would motivate the client towards premature termination of informing.

Law of Abandoned Expertise: Psychologists have long known that individuals are motivated to achieve high performance, irrespective of whatever rewards may be received. Many individuals are similarly motivated by the process of achieving mastery over a particular domain of knowledge (Elliot & Harackiewicz, 1996). Once an individual has achieved expert status, performance becomes nearly effortless—thanks to knowledge compilation, the cognitive demands of the task are not overly great—and a sense of mastery is achieved. Based on this, we would expect individuals to prize their expertise and to be very reluctant to give it up. This phenomenon has been proposed in the form of the behavioral *Law of Abandoned Expertise* (T. G. Gill, 2008a):

> *Hypothesis:* Clients will resist any task-related informing activities that require relinquishing existing expertise in their problem space.

Many different sources of evidence support the view that this law—if not *always* true—is at least true a great deal of the time. There are many examples of students who are remarkably unwilling to abandon their pre-conceived notions even in classes where graphic experimental demonstrations of the weakness of their prior beliefs have been presented (Bain, 2004). Scientists refuse to relinquish paradigms even in the presence of strong evidence that their view is incorrect (Kuhn, 1970). Pre-existing notions prevent the adoption of even simple procedures, such as boiling unsanitary water to avoid illness (Rogers, 2003). The behavior in the naval gunfire example clearly illustrated this law. How else can one explain the refusal of the Bureau of Naval Ordnance's to investigate further when Sims originally sent in his findings?

Obviously, we would expect the abandoned expertise phenomenon to be particularly severe where the sender is attempting to convey information to the client that is inconsistent with the client's existing concepts, theories, or practices. Unfortunately, practitioner and academic expert knowledge nearly always exhibit such inconsistencies owing to their fundamentally different structures (see Figure 2). This difference in mental models is proposed to be a major source of the deplorable state of academic-practitioner communications in some disciplines, such as management and MIS (T. G. Gill, 2008a).

Arousal Motivation

The next category of intrinsic motivator relates to arousal. From an informing perspective, it is most likely to impact the client's willingness to attend to the channel.

Unlike control and performance motivations, motivation for arousal is not unlimited. Although we may have a cognitive motivation for information seeking (Driver & Streufert, 1969) and variety (Hackman &

Oldham, 1980), the cognitive demands of too much arousal can lead to stress, or even panic (Streufert & Streufert, 1978), sometimes referred to as "information overload". As a consequence, the motivational character of arousal is generally plotted as an inverted-U, with desired arousal being an intermediate value that is not too great—leading to overload—but also not too low—leading to boredom.

Unexpected. Informing that falls within the appropriate arousal bounds will sometimes be termed interesting. In a widely cited article relating to the social sciences, Davis (1971) emphasizes that research, in order to be interesting, must contain an element of the unexpected. Research whose sole purpose is to support an existing paradigm may be useful, but it will not be interesting. Because unexpected information requires the creation of new structures, it will lead to greater client arousal than communicated concepts that are already incorporated within existing client models. The motivation for such arousal is not unbounded, however. As evidence of the inverted-U shape, Davis further argues that the sender can also exceed the client's capacity to accept the unexpected. In a statement that also supports the Law of Abandoned Expertise, he asserts:

> Yet one must be careful not to go too far. There is a fine but definite line between asserting the surprising and asserting the shocking, between the interesting and the absurd. An interesting proposition, we saw, was one that denied the weakly held assumptions of its audience. But those who attempt to deny the strongly held assumptions of their audience will have their very sanity called into question. They will be accused of being lunatics; if scientists, they will be called 'crackpots'. If the difference between the inspired and the insane is only in the degree of tenacity of the particular audience assumptions they choose to attack, it is perhaps for this reason that genius has always been considered close to madness. (Davis, 1971, p. 343)

Distractibility. Another arousal-related phenomenon that impacts informing, at the opposite side of the scale from information overload, is distractibility. Human cognitive systems are not like the single-process computers of the 1950s and early-1960s. They often attend to a number of tasks concurrently, at different levels of arousal, and focused attention can shift from task to task in the event that optimal arousal levels are not being achieved in the most highly attended channel. Indeed, distractibility is so common and significant in its impact that one of the most serious criticisms that a cognitive scientist can make against any proposed model of cognition is that it does not account for the phenomenon (Newell, 1990, p. 227).

One area where the nature of distractibility and attention has been studied extensively is in the advertising industry, where senders pay large sums of money to inform clients in a very short period of time. In one study (Lord & Burnkrant, 1993), for example, researchers examined how the interest generated by program content interacted with the attention paid to commercials within the program. They found many levels of interaction between interest in the program, interest in the commercial, and use of an attention-grabbing device (audio beeps for the low involvement commercial for an oil product, a compelling visual image for the high involvement commercial involving drunk driving). The relationships they found were quite complex. For example, where program involvement was high, a high-involvement commercial combined with use of the attention grabbing device threatened to distract clients from the message. Low involvement commercials, on the other hand, benefitted from the high level of arousal carrying over from the high-involvement program. On the other hand, where program-involvement was low a high-involvement commercial fared better, and the attention grabbing device generally seemed warranted. The complexity of the results arising from this relatively simple stream of research suggest that it will be difficult to devise general principles for predicting how to format messages that garner optimal attention in the presence of distractibility.

Interference. Another aspect of arousal from an informing channel is its ability to interfere with other cognitive processes. An example of this can be found in teenage driving:

> A recent study found that a teenage driver driving alone was 40 percent more likely to get into an accident than an adult. But with one other teenager in the car, the percentage was twice that—and with a third teenager along for the ride, the percentage doubled again. (Ulene, 2007, as cited in Arielly, 2008).

In this example, the informing channels that interfered with the task were unrelated to the task. It is also perfectly plausible that—for some activities—the informing activities of the task could interfere with other cognitive activities of the task. For example, if a conference presentation is particularly engaging the moderator may forget to check the clock, thereby interfering with his or her assigned task of ensuring that subsequent presenters have a fair allocation of time.

Control Motivation

The final category of intrinsic motivators to be examined is control. From in informing perspective, it is most likely to impact client willingness to change existing mental models.

The sense of control over your activities and their outcomes is a powerful motivational force (Gilbert, 2007). Client motivation to be informed should therefore be impacted by whether or not the expected impact of the informing is greater client control over the task or less control. As an example, a study of expert system usage found a highly significant relationship between continuing use and the change in user discretion (i.e., control) that accompanied adopting the system (T. G. Gill, 1996). After controlling for the quality of system performance, where discretion increased, continued usage was high. Where discretion declined, far more systems were abandoned.

Illusions of Control (e.g., Thompson, 2004). Individuals frequently perceive that they have greater control over a task than is actually the case. For example:

> …people bet more money on games of chance when their opponents seemed incompetent than competent—as though they believed they could control the random drawing of cards from the deck and thus take advantage of a weak opponent. People feel more certain that they will win the lottery if they can control the number on their ticket, and they feel more confident that they will win a dice toss if they can throw the dice themselves (Langer, 1975, and Dunn & Wilson, 1991, as cited in Gilbert, 2007, p. 22)

Where such a perception exists, we would expect that motivation to be informed will decline. Moreover, visceral influences also appear to exert an influence over this particular illusion: depressed people have a reduced sense of control, whereas individuals in a positive mood are more likely to experience this illusion. Similarly, individuals having a high level of desire for a particular task outcome tend to perceive that they have control (Thompson, 2004).

Resonance and Visceral Factors

Visceral factors include emotions and feelings—sometimes referred to collectively as *affect* within the psychology and management literatures—as well as drives (e.g., hunger, thirst, sex), moods, and pain (Loewenstein, 1996). These can play an important role in the informing process. Unlike performance, arousal, and control, however, many of the sources of visceral factors are not tied to the task-related content of the informing message or the task being performed.

Visceral factors have the potential to impact virtually every aspect of the informing process, and a full treatment of the subject is beyond the scope of this paper. Instead, we need to content ourselves with describing some of the mechanisms through which these factors, particularly emotions, may impact the informing process. Specifically, we consider:

- Impacts of visceral factors on cognitive functions
- Impacts of visceral factors on choice processes
- Impacts of anticipated emotions and feelings
- Impacts of social factors

We begin, however, by distinguishing what we mean by emotions and feelings.

Emotions versus Feelings

Prior to considering the impact of emotion and feelings on informing, it is useful to distinguish between the two. As illustrated in Figure 4, emotion is viewed as a psychological state, often brought on by an event. That psychological state, in turn, may induce physiological and cognitive changes. Our subjective perceptions of these changes become our feelings. As a result, in research where emotion levels are based upon self-reports, what is being observed can often more accurately be characterized as feelings. Although emotions and feelings are often lumped together, the distinction appears to have a physiological basis (Dolan, 2002).

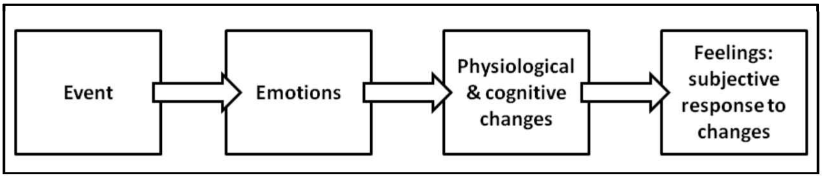

Figure 4: Emotions and Feelings

Visceral Factors and Cognitive Functions

Visceral factors have the ability to impact cognitive functions in many ways. Many of these resemble the task-related filters already discussed except that their source is extrinsic to the task. A number of the effects that have been observed are now described.

Emotions and information processing: Emotions can change the client's ability to process information. For example, a number of important emotion-related effects on information processing in the human cognitive system have been observed (Dolan, 2002):

- *Processing priority*: Emotion-laden information cues appear to get a higher priority when compared with other sensory and cognitive cues.
- *Enhanced memory of emotionally significant events*: Conditioning experiments support anecdotal evidence that when emotionally significant events (e.g., the Challenger disaster) occur, they enter memory more effectively.
- *Recalling past emotion-laden effects decision-making*: Specifically, when such states are evoked they can bias decisions either towards or against similar decisions, depending upon the emotions recalled.

Interference. As was the case with arousal related to information flows, visceral and emotional arousal can interfere with cognitive functions, including those related to informing. In the presence of strong arousal from visceral factors, individuals will frequently *and knowingly* act in ways that are inconsistent with their own long term self interest (Loewenstein, 1996). A rather graphic demonstration of the impact of such factors occurred in an experiment that examined how sexual arousal influenced decision-making and judgment (Ariely & Loewenstein, 2006). Subjects, in various states of physical arousal, were asked to rate their attitudes towards various questionable sex-related practices (e.g., safe sex, lying in order to get sex, continuing to pursue sex after a refusal). Uniformly, and highly significantly, their willingness to engage in questionable practices grew with their level of physical arousal.

The ability of visceral factors—in this case, anger—to interfere with informing was also amply demonstrated in the later stages of the naval gunnery case. By the time the process had degenerated into name-calling, it is doubtful that any informing was taking place, despite the fact that information was being transmitted.

In considering the impact of visceral factors, a number of propositions are advanced that are particularly likely to be relevant in a client-sender context (Loewenstein, 1996, p. 278):

i. We tend to become less altruistic than we would like to be when visceral factors intensify.

ii. When making decisions for another person, we tend to ignore or give little weight to visceral factors they are experiencing

iii. Increasing the intensity of a visceral factor for ourselves and another person in parallel leads to a decline in altruism.

iv. When we experience a particular visceral factor, we tend to imagine others experiencing it as well, regardless of whether they actually are.

v. People underestimate the impact of visceral factors on other people's behavior.

In the context of informing, this suggests that the sender will expect the client to be a rational party to the informing process even when the sender personally recognizes that visceral factors are influencing his or her own actions. The same would apply to the client's perception of the sender. Given the high potential for influence on cognitive processes of such factors, the failure to recognize their presence on either the client or sender side can present a serious barrier to informing. Like many other effects mentioned in this paper, this barrier could be considerably intensified in situations where channels of low media richness are employed. For example, discussion group trolling (Herring, Job-Sluder, Scheckler, & Barab, 2002) and email flaming (Alonzo & Aiken, 2004) both represent behaviors that interfere with effective informing. Both are posited to have a strong visceral component (e.g., Alonzo & Aiken, 2004). Experience also tells us that similar disruptive behaviors occur much less likely frequently when a media-rich face-to-face channel is used.

Priming. A particularly remarkable demonstration of the power of visceral influences and emotional state to impact cognition can be found in the phenomenon of *priming* (e.g., Gladwell, 2005). Priming occurs when mere exposure to certain words and behaviors prior to an activity exert a strong impact on subsequent performance of that activity. Experimental psychologists use priming frequently; it proves to be a very useful tool in laboratory studies where the impact of emotional state on cognition or learning is being tested. Numerous examples exist of the phenomenon, which can be astonishingly powerful in its impact. For example:

> Two Dutch researchers did a study in which they had groups of students answer forty-two demanding questions from the board game Trivial Pursuit. Half were asked to take five minutes beforehand to think about what it means to be a professor and write down everything that came to mind. Those students got 55.6 percent of the questions right. The other half of the students were asked to first sit and think about soccer hooligans. They ended up getting 42.6 percent of the Trivial Pursuit questions right. The "professor" group didn't know any more than the "soccer hooligan" group. They were simply in a "smart" frame of mind… (Dijksterhuis & van Knippenberg, 1998, as cited in Gladwell, 2005, p. 56)

Priming can also impact how we experience and disambiguate stimuli—a critical element in informing processes. For example:

> …volunteers in one study were told that they would be eating a delicious but unhealthy ice cream sundae (ice cream eaters), and others were told that they would be eating a bitter but healthful plate of fresh kale (kale eaters). Before actually eating these foods, the researchers asked volunteers to rate the similarity of a number of foods, including ice cream sundaes, kale, and Spam (which everyone considered both unpalatable and unhealthful). The results showed that ice cream eaters thought Spam was more like kale than it was like ice cream. Why? Because for some odd reason, ice cream eaters were

> thinking about food in terms of its *taste*… On the other hand, kale eaters thought that Spam was more like ice cream than it was like kale. Why? Because for some odd reason, kale eaters were thinking about food in terms of its *healthfulness*… (Gilbert, 2007, pp. 159-160).

From a conceptual standpoint, priming effects are similar to framing and anchoring except that they occur entirely outside of the task being performed. As was the case for framing and anchoring, we'd expect the effects of priming to be most pronounced for less familiar activities. Also, particularly where the sender-client channel involves information technology and is not face-to-face, the presence of client priming stimuli may well be unknown to and beyond the control of the sender.

Emotions and Choice

There are a number of visceral counterparts to the mental model effects of framing, anchoring, and choice strategies that have been observed. These seem to be particularly pronounced when emotions are involved, although we would expect that other visceral factors could exert a similar influence.

Emotional framing. Effects similar to framing may also be observed that have a distinct emotional component. We refer to these as emotional framing. One example involves the presence of money. Numerous experiments demonstrate that when money is involved, different preferences and behaviors are exhibited than if non-money equivalents are used and that such attitudes cross the line into non-economic contexts. Individuals, for example, are found to be much more likely to cheat when money is not directly involved (Ariely, 2008). The influence of money can also explain, for example, the widely observed phenomenon that consumers spend more when using credit cards than when using cash—even consumers who pay their entire balances each month—and why such spending further increases based on the size of unused credit limits (Soman & Cheema, 2002).

Similar emotional impacts on rational decision making can be found in the phenomenon described as "auction fever" (Ku, Malhotra, & Murnighan, 2005). As noted in the article:

> In 1999, Chicago sponsored a public art exhibit of over 300 life-sized fiberglass cows that culminated in 140 Internet and

> live, in person auctions. Collectively, the cows sold for almost seven times their initial estimates. (Ku et al., 2005, p. 89)

The nature of the frenzy observed by the researchers caused them to attribute the unexpected valuations to competitive arousal, an emotional reaction to the auction process leading buyers to depart from intended behaviors.

Although the second of these examples could be attributed to the unfamiliarity of the situation—how often do most people purchase fiberglass cows at auction?—the first example, credit cards being used more freely than cash, cannot. Thus, it is quite plausible that the impact of visceral framing may extend to routine, as well as non-routine, decisions.

Emotional anchoring. Similar to framing, anchoring can occur on an emotional level, as well as on a purely cognitive level. In politics, for example, candidates frequently attempt to draw parallels between their own background and those of other loved politicians, at the same time noting distinctions between themselves and other hated politicians. A particularly famous example of this occurred in the 1988 U.S. presidential campaign, during the vice presidential debate. In prior speeches one candidate, Senator Dan Quayle, had often identified similarities between his own background and that of John F. Kennedy, whose tragic death in office still evokes a strong emotional response in many Americans. His opponent, Senator Lloyd Bentsen, aware of these past comparisons, waited for Quayle to make a similar comparison during a televised debate. When Quayle did, Bentsen then made the emotional response:

> Senator, I served with Jack Kennedy, I knew Jack Kennedy, Jack Kennedy was a friend of mine. Senator, you are no Jack Kennedy. (Commission on Presidential Debates, 2004)

That statement completely negated the attempted anchoring, as well as becoming the most famous rejoinder ever made during a vice-presidential debate.

Emotional impact on choice strategies. Emotions have been found to play a direct role in decisions involving choice. For example, individuals who are given a set of alternatives and attributes find it more difficult to make trade-offs of emotion-laden attributes for money than less emotion-laden attributes (Luce, Payne, & Bettman, 1999). There is also considerable evidence of the impact of emotional state on the perception of products and on the weighting placed on different product attributes (Adval, 2001). Viewed in the context of prospect theory—a cognitive model for evaluating uncertain and distant outcomes—emotions have been found to impact both perceived outcome values and the weight attached to uncertainty and time preferences when discounting (Rottenstreich & Shu, 2004). As a consequence, emotions can, potentially, distort the informing process in much the same manner as purely cognitive choice heuristics. This is particularly true in situations where the sender is not cognizant of the client's emotions, as would be the case where non-rich media are used as the channel (Daft et al., 1987).

Anticipated Feelings

Emotions and feelings may be generated as a consequence of being informed. Where this is the case, the decision to engage in the informing process may be impacted by what the client expects to feel, rather than by what is actually felt. This effect may be amplified by the fact that anticipated feelings are often far greater than the actual feelings that are later experienced (Gilbert, 2007), in which manner they differ from most of the other visceral factors (which tend to be underestimated).

Procrastination. One example of how anticipated emotions can impact informing involves procrastination. If the anticipation of poor performance or failure is strong, a client may avoid attending to the informing system. Consider, for example, the following explanation provided by a distance learning student for her failure to attend to the course syllabus:

> What used to be a simple schedule and list of assignments, two pages at most, has become an intimidating document, often a dozen pages long, filled with mandatory administrative policies, honor codes, disability and religious accommodations, complex tables with Web links and even the occasional contractual agreement between instructors and students. Although I'm starting to learn about these things, I still have a strong flight reflex that leads me to avoid that which I cannot immediately understand and prevents me from actively seeking that which I do not want to know. (C. Gill, 2006)

Cheating. Cheating is another example of a behavior through which (desired) informing channels are not attended. One study that specifically examined the impact of anticipated emotions on willingness to cheat found that the anticipated elation associated with cheating was an important antecedent of willingness to cheat—much more so than anticipated regret (Sierra & Hyman, 2006).

Refusal to be informed. Anticipated emotions can also play a powerful role in the refusal to learn. One particularly common version of this phenomenon is those situations where the client perceives that by accepting the information, his or her mental models will become at odds with prevailing models in the social network. In the opening example of *Diffusion of Innovations* (Rogers, 2003, p. 1-5), a case study is presented of a Peruvian village in which existing mental models of health were based upon a dichotomy of "hot" and "cold", where "hot" was associated with illness and "cold" was associated with health. The attempts of a health worker to get the community to adopt the practice of boiling water to improve sanitation were largely unsuccessful. This was attributed to the fact that any individual following this practice would be at odds with the prevailing wisdom and behaviors of the community. Indeed, the two examples where the informing effort was successful were in the case of a woman who was already ill—and therefore expected to favor "hot"—and an outsider family, who had moved from another area where the hot-code dichotomy did not exist.

Social Factors

It is very likely that many of the examples previously cited as evidence for the Law of Abandoned Expertise also have social components that amplify the task-specific effect of the proposed law. We saw this demonstrated in the previous example of the Peruvian village. Similar examples closer to home are also readily available. The student who adopts models or behaviors at odds with his or her peers may be castigated. The scholar who is swayed by evidence that is contrary existing paradigms may become isolated from colleagues. The middle manager who comes to believe in an unconventional idea, however strong the evidence supporting that idea may be, risks losing credibility and stature in the eyes of both employees and executives.

Conceptually, we can view the social factors that impact motivation to be informed as being somewhat parallel in structure to the intrinsic motivational factors that operate at the task level (T. G. Gill &

Saunders, 1997). For example, the social constructs of power, dependence, and autonomy map well into control. Both performance and arousal can be viewed in a broader social context rather than being limited to the task itself. For example, the intrinsic benefits of mastery can easily translate into status in a social setting. The arousal experienced during many informing communications will likely have both an informational task-related component and a social component. Indeed, there is an entire category of job described as "emotional labor" (Morris & Feldman, 1996)—which includes many types of customer service activities—for which conveying proper emotions and engaging customers in a personal way are considered more important than the associated information-conveying function of the job. How much the emotional and social aspects of informing will impact the client's willingness to change existing mental models is likely to depend heavily on the context of the informing. Nonetheless, if we fail to take into account our client's perspective on the anticipated emotional and social consequences of both the informing process and of being informed, the likelihood that informing will be disrupted or distorted in some fashion is great.

Client-to-Client Resonance

Given the number of filters that could potentially interfere with informing in low-structure situations, it sometimes seems remarkable that low structure informing ever takes place. Actually, this observation is closer to the truth than we might care to believe. In fact, if we really want such informing to take place, our best prospect comes from having a sender with highly reliable insights into the expected nature of those filters. It stands to reason, therefore, that some of the most reliable senders would be individuals very similar in characteristics to the client. Or, simply stated, the most plausible informer would seem to be another client.

Diffusion Models

As it turns out, the intuition that clients would be particularly effective at informing other clients is not misplaced. In fact, client-to-client informing appears to play the dominant role in many knowledge diffusion processes. This contention is supported by the huge literature on the diffusion of innovations (as of 2003, an estimated 5200 publications on the subject; Rogers, 2003, p. xvii). The seminal book in the field, *Diffusion of Innovations (now in its 5th edition)*, was written by Everett Rogers, a researcher whose pioneering studies of diffusion were conducted in the 1950s after patterns started to become apparent in the adoption of farming technologies during the 1930s and 1940s. Some of the key findings from this research stream, as summarized by Rogers, are as follows:

- Certain characteristics tend to make some innovations easier to diffuse than others. Examples of these are simplicity, compatibility with previous models or ideas, relative advantage compared to previous ideas, trialability (the ability to try out the innovation prior to adopting it), and observability (Rogers, 2003, p. 222). Ideas without these characteristics take much longer to diffuse.

- Diffusion does not occur immediately but, instead, through a gradual process of adoption within the client community. Two forces that are particularly important for this process are mass media (i.e., any communication where a single sender provides information to multiple clients concurrently) and interpersonal communications within the client network. In general, mass media communications are more important in the earlier stages of communications, while interpersonal communications dominate later stages (Mahajan, Muller, & Bass, 1991, cited in Rogers, 2003).

- Diffusion processes often have to reach a "critical mass" after which diffusion starts to take off at a very rapid rate (Rogers, 2003, p. 349).

- Individuals within client communities are not homogeneous. Rather, they exhibit different characteristics with respect to their willingness to adopt innovations. These may be modeled in terms of thresholds (Rogers, 2003, p. 355). Idealized categories of adopters are often classified as: innovators, early adopters, early majority, late majority, and laggards (Rogers, 2003). Individuals may also exhibit different degrees of influence on other clients in the community (e.g., opinion leaders; Rogers, 2003, p. 300), awareness of the social nature of the community (e.g., key informants; Rogers, 2003, p. 310), and willingness to venture outside of their community and cumulative past experience (innovators; Rogers, 2003, p. 282).

Because mass media exerts its influence on the most receptive portions of the client community (i.e., innovators), we can expect that interpersonal client-to-client communications will play a much more critical role in idea diffusion as the complexity of the idea grows.

Tipping Points

The *Tipping Point* model (Gladwell, 2000) further synthesizes these findings into a series of general principles that guide the flow of information in human systems. The concept of "critical mass" in innovation theory is restated in terms of *tipping points*. As these points are reached, the level of communication of a particular idea within a social system suddenly jumps dramatically. Gladwell organizes his findings into four central themes:

1. *The Law of the Few* (Gladwell, 2000, p. 30): Three types of individuals play a particularly critical role in the diffusion of information within social systems. *Connectors* maintain active communications links with an unusually large number of individuals within and outside of the immediate social network. For example, given a random set of last names from a phonebook, a connector might be able to identify personal connections with 3-10 times as many names as the average individual. *Mavens* act as sinks for information, gathering information from many sources and willingly sharing it with others in the community. *Salesmen*, whom we will refer to as *Persuaders*, are unusually good at convincing other individuals to adopt a particular product or idea.

2. *The Stickiness Factor* (Gladwell, 2000, p. 30): As mentioned previously during the discussion of criticality, certain characteristics of a communication (e.g., simplicity, unexpectedness, concreteness, credibility, emotional impact, story setting; Heath & Heath, 2007) make it particularly likely to be retained by a client.

3. *The Power of Context, Part I* (Gladwell, 2000, p. 133): Small aspects of the decision-making setting can exert a huge influence on overall decision-making.

4. *The Power of Context, Part II* (Gladwell, 2000, p. 169): The effective size of a social community is limited to roughly 150

participants. Beyond this point, there is insufficient cohesion for consistent messages to be shared among all members.

Common to diffusion models, the key participants involved in moving information within the client community are, themselves, members of that community. The only exception to this is connectors, who often serve the role of connecting disparate communities together. The impact of these participants on the speed of diffusion is explored in Gill (2008b).

Network Models

One obvious limitation of simple diffusion and tipping point models is that they fail to capture the specific communications patterns associated with a particular informing situation. Studying the impact of topology on informing effectiveness is domain of network models of communications. Two of these models are widely used, the small world model (Watts, 2003) and the scale-free model (Barabasi, 2002).

In the small world model (e.g, Watts, 2003), for example, closely linked sub-communities are linked by infrequent links between communities, as shown in Figure 5. This is similar to the topology presented in the tipping point model. These might be viewed in terms of connectors. The small world model, however, does not appear to have analogs to mavens or persuaders.

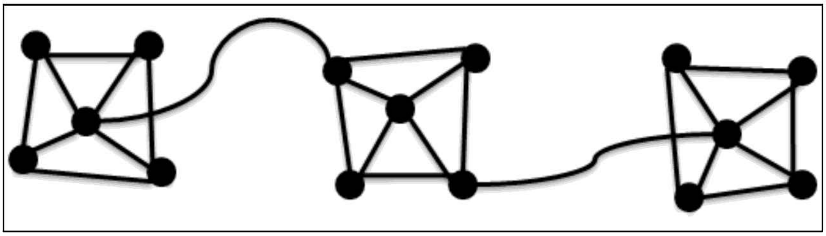

Figure 5: Small world model (Watt, 2003), showing tightly connected clusters tied together by a small number of cross cluster links. Such networks can arise, for example, when individuals link to affiliated (e.g., closely linked) networks but may have more than one affiliation. For example, a faculty member could be linked to other faculty in his or her college (geographic affiliation) while also being tightly linked to the members of his or her discipline (which would not be geographically constrained in the same way).

In the scale free network model (e.g., Barabasi, 2002), connection densities of nodes are governed by a power law, rather than by a more typical normal distribution. Such a network naturally evolves under circumstances where new nodes gravitate towards connections with existing nodes that are highly connected ("the rich get richer", Barabasi, 2002, p. 79). As networks grow large, this will naturally lead to the emergence of hub nodes that play a particular influential role in enabling communications across the system, as shown in Figure 6. The hub node, therefore, plays a similar role to the connector nodes of tipping point model.

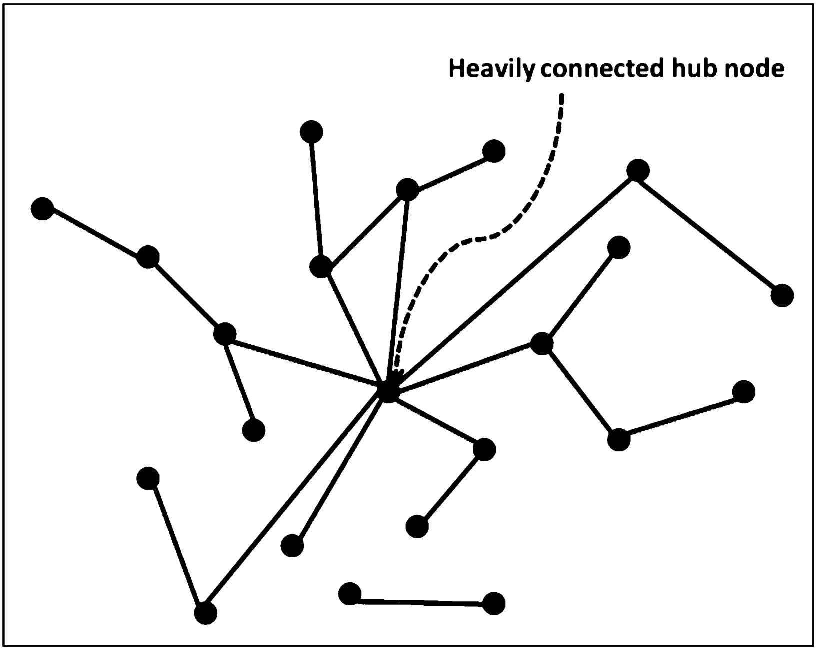

Figure 6: Representation of scale-free network with emergent heavily connected hub node. In a scale free model, the logarithm of the likelihood of any given number of connections for a particular node declines proportionately to the logarithm of the number of connections.

Barabasi's (2002) scale free model also introduces the notion that node fitness, in addition to the number of connections, might influence the likelihood of further connections. This would suggest, as a possibility, that mavens might tend to acquire more connections than the typical individual—a proposition that could be tested as a hypothesis.

Conclusions

For about half a century academic researchers in business—and other disciplines as well—have been debating whether our research should be focusing on rigor or relevance. In engaging in that debate, many of us seem to have lost sight of the fact that how we inform our clients of what we have done is likely to be just as important a factor in impacting our clients as the quality (rigor) and potential usefulness (relevance) of what we have discovered. The informing sciences are uniquely positioned to bring this message to the research community.

The resonance models proposed in this chapter are probably better characterized as a research agenda than a theory. What it attempts to do is to organize a large number of observations, almost none of which were gathered with the study of informing in mind, into a theory-based framework that helps clarify what we know, what we suppose, and where we are still largely uncertain. As more systematic research is conducted and more perspectives are gathered, the contents of the framework will doubtless grow and need modifications. As research is conducted in areas where we are unsure, perhaps we will be able to reduce the amount of uncertainty that remains.

As we look forward towards future research, it is important to recognize that resonance is manifested in two forms: 1) in the single client resonance model, we are concerned with informing that changes the mental models of an individual client, 2) in the client-to-client resonance model, we are concerned with identifying those characteristics that support diffusion through a broader client community—a process that often experiences sharp spikes in informing commonly referred to as “tipping points”. Depending upon our objectives, studying one type of resonance or the other may serve our needs. In many circumstances, however, effective informing will involve both—since diffusion necessary starts with informing a single client but has little impact if the clients we inform do not then proceed to inform others.

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PART III: PERSPECTIVES ON INFORMING SCIENCE

Chapter 10

Informing for Operations: The First Principia

Zbigniew J. Gackowski

Introduction

Many streams of research deal with informing, a real interdisciplinary mix: cybernetics (a study of communication and control processes), operations research (analysis of processes for decision making), operations management, systems theory, systems analysis, praxiology (a study of human conduct), ethics, psychology, sociology, political science, etc. The 20th century has become known as the century of the theory of relativity, quantum mechanics in physics, nuclear energy, electronics, aviation, computing, and space exploration. The 21st century emerges at least as the century of information, microbiology, bioengineering, nanotechnology, and quantum computing.

Information - anything *in form* that can be communicated, similar to anything *in substance* that must be transported, operates among all of the at least partially autonomously acting entities. Information, broader knowledge as data, relationships among them and rules of reasoning and proceeding, concepts, and wisdom are factors of power similar to other resources under one's control. Studies of informing, information, and information quality shed a new light on many issues. Operations conducted by humans or robots depend on available or obtainable operation factors in substance or in form. In decision making, factors are represented by variables. Decision makers assume that and act as if the knowledge available to them represents the reality they deal with.

There is a wide spectrum of operations, if assessed by complexity. At the lowest end, actions may be purely reactive to changes of the environment such as it occurs in physical inert objects and primitive forms of life. At the highest end, operations may follow sophisticated patterns of behavior or reasoning that may be related to remote future goals and purposes of complex hierarchical systems that consist of interacting entities that may be complex on their own.

The more complex a system of operations is, the higher the level of making decisions, the fewer contacts decision makers experience with factors of substance, the more they rely on factors in form, and the less they are in direct contact with the reality they seemingly control. Political or corporate leaders actually act within a virtual reality of representations made available to them by others of influence; this was in antiquity and is now, with no visible end in the future.

Despite the virtual nature of indirectly perceived realities, information and informing are physical. They are subject to the same physical laws as the rest of the physical world. Operations conducted by humans also manifest aspects of a psychological, sociological, political, and ethical nature. This chapter does not understate their significance but limits its scope. Nevertheless, it is written from a position that can be expressed by the following statements:

1. Science, including Informing Science, is "*beyond evil and good,*" paraphrasing Nietzsche; hence, it should be assessed concerning only how faithfully it maps or represents reality.
2. In reality, "*there is no thing inherently good or evil but the manner in which it is used,*" paraphrasing Thomas Aquinas; hence one must always separate the object from its use. Thus,
3. With "informing for operations," there are contributions to "informing," "operations," or both. These contributions should be assessed by how each of them respectively improves the effectiveness or efficiency of operations. Nevertheless, in a social environment, ethics may, and should be, considered as well.

The physical aspects of information and informing for operations should be studied first. Only on top of solid physical foundations may one successfully add other aspects, if necessary. Informing for operations offers an insight into the subject with results of more lasting theoretical and practical validity. The explosive pervasiveness of computing and information technology obscured the fact that, frequently, the ultimate purpose of informing is simply to improve the effectiveness and efficiency of any human-controlled operations. Informing also extends our knowledge and, subsequently, the control of our environment, whether physical or social. The physical approach to modeling of informing encompasses basic distinctions, main point of reference, observation points, observers, frame of reference, and a yardstick to measure results. To facilitate the initial reading, this chapter presents the concepts in a qualitative narrative. To minimize ambiguity, the more formal definitions have been numbered and placed in the Appendix. The physical approach facilitates identification of the first universal principles that operate in this domain as fundamental laws - principia.

Informing and MIS

Before proceeding to examine the fundamental principles that apply to informing in operations, it is useful to consider how informing is addressed in other disciplines. Within business-related disciplines, MIS seems the most applicable. Here, the closest proxy of informing, without directly addressing it, is the Framework for Research in Computer-Based (C-B) Management Information Systems by Ives et al. (1980). It served as the recognized framework for hundreds of doctoral dissertations in MIS for more than 25 years.

Its authors claim that the major use of their framework is to generate relevant testable hypotheses for MIS research. The offered examples confirm Mendes's (2005) contribution titled "*The Poverty of Empiricism*" (p. 189). Only four (1.2%) of the 331 dissertations "*specifically develop performance measures for the development, operations or use process*es"; "*descriptions have been over used and discovery research has been underutilized*" (Ives et al., 1980, p. 930). A cursory survey of MIS textbooks seems to confirm that those dissertations had no significant impact on the MIS field (Gackowski, 2007).

Any model capable of becoming a rallying point for a broader community of researchers and of yielding research results of lasting validity should entail an explicitly or implicitly well-defined point of reference, observation point, and frame of reference. They are fundamental to the success of theoretical physics and indispensable for researchers exploring new domains as the triangulation points for navigators. Research should not be limited to computer-based management information systems. Such a limitation encourages researchers to focus their attention disproportionately on technology rather than on the underlying problem itself. Then researchers become naturally biased toward metrics of performance. Such an approach may be appropriate to particular classes of solutions that are not necessarily the ones dictated by the informing situation—such as system use. A much less limiting perspective is to focus on how effectively, ethically, and efficiently management is informed by whatever means.

Informing and quality of data in operations deserve a more rigorous approach. If rigor and quality of data are not assured, it renders information technology ineffective and underutilized—even a wasted resource. Informing, as computing, serves human endeavors. It should be assessed from the same perspective.

Philosophical Roots of Informing

The approach to informing presented in this chapter is grounded in concepts derived from many disciplines.

In informing for operations, **Schopenhauer**'s worldview plays a fundamental role. In his opus vitae, "*The world as will and representation*" (made available to English readers by Hamlyn, 1980), he provides a consistent bipolar philosophical framework fitting informing for operations. He views actions or operations as interplays between will and representations where,

- **will** is an all-pervasive drive in nature that imposes itself on everything—objects and subjects, on the environment in today's parlance. Will provides a **sufficient reason** to act. With humans, will is the **highest form of energy** known in the universe, both creative and destructive; hence, to serve us well, it must be channelled as any other form of energy.

- for acting subjects, **representation** is the **only reality**. Their will is an objectification of the will in general. In operations, it is the will of decision makers who act based not on the actual reality but on the **representation of that reality**, whether adequate or not. In today's parlance, it consists of information, data, knowledge, concepts, and wisdom as the consecutive steps in the staircase of human cognition that constitute the virtual reality upon which they act. It plays out this way at all levels of decision making—at the strategic level in particular. Actions may merely be reactions to the changes in representation or may result from reasoning of the intellect or the inference engines of the artificial intelligence.

Schopenhauer's worldview also offers implications that he never explicitly spelled out. Due to the imposing pressure of will,

- all communications among living entities are usually **misinformation**, if not outright **disinformation,** while **valid information** is, alas, as history attests, a rare exception more often than we expect. We barely can validate routine facts, while the mysteries of nature are far from being fully recognized—barely at some acceptable level for practical activities. Observations and communications are always distorted by random errors and are **biased** intentionally, subconsciously, or out of ignorance. This **undermines the quality** of all informing. Misinformation is the norm, and disinformation is to be expected and dealt with. These are not random deviations from the truth, as frequently imprudently assumed. Science seeks valid information/data, while operations need effective, ethical, and/or efficient information/data.
- actions are guided by the subjects' **purpose**; hence, it is the only legitimate **point of reference** for assessing operations; it calls for a teleological approach to informing.

Aristotle defined quality as something that enables one to distinguish and define objects. This is the starting point for discussing information quality in operations before embarking on a deeper inquiry into the seemingly chaotic plethora of conditions that must be met for information to be effective in operations.

Nietzsche's (2007) major contribution to the theory of knowledge is perspectivism that offers a useful guideline: "*Knowledge is always perspectival … knowledge from no point of view is as incoherent a notion as seeing from no particular vantage point. The notion of an all-inclusive perspective is as incoherent as the concept of seeing on object from every possible vantage point simultaneously.*"

Initially, when one ignores the dynamics of changes, there are an infinite number of possible perspectives, such as the number of points on the surface of a sphere with the observed object in its center. From some viewpoints, one cannot see much, while from other points, as from a hilltop, nearly everything is visible. To discover the most fruitful perspective is an insight. There is only a chance of one in infinity (zero) of finding such a perspective. With inert systems, the selection of the main point of reference is always important, although it does not determine the ultimate practical outcomes of research. Astronomers described and predicted the movements of celestial bodies, and navigators calculated their positions, whether by using a geocentric or heliocentric assumption of the planetary system; however, the latter is simpler and closer to reality. Whatever the outcome is, it can be mathematically transformed from one system of reference to another. Then the ontological, physical, or chemical view of properties may suffice but not with operations controlled by humans. Will provides a sufficient reason to act. It can be controlled by intellect and/or emotions; hence, it should be assessed from the perspective of the actor's purpose, interest, circumstances, and state of emotions.

Dewey, the pragmatist, in his *Theory of Inquiry* (Magee, 2000, p. 293) departs from the usually assumed and aimed-at objectivity of scientific observations. He views observers as **active, interested decision makers and agents in the middle of the situation** in contrast to the usually postulated **objective observer** in natural sciences. Then factors and their properties can be assessed and understood better when viewed from the perspective of the main purpose of informing for operations.

Einstein, the father of **relativity,** brings to our attention what is obvious today in the universe but ignored in informing for operations, postulate of perspectivism and relativity. As long as the purpose—the point of reference and the frame of reference—do not change, significant factors and their quality aspects are assessed the same way and are subject to the same operating principles. It is the essence of the postulate of perspectivism and relativity of measurement, observations, and views.

Here, relativity is used in its restricted sense as defined by Einstein (1961, p. 13). At first, it pertains to operations oriented toward a constant purpose (the equivalent of inertial frames in physics for uniform motion or translation as meant in physics) and next for operations with changing purposes (the analog of added rotational displacement in mechanics). In our earthly reality, the restricted relativity suffices.

While witnessing the exploration of space in full swing, with international competition and/or collaboration, one easily can see the emerging need for a theory of operations that will also account for the general theory of relativity where *"time and space lose their traditional role as fixed frames of reference to become reduced to structural qualities of the field"* (1961, p. 155) under investigation - operations that reach beyond planet Earth.

Economy: Among living entities, economy and efficiency of operations, if not with respect to an individual entity but particularly for specie, are the only criteria. Informing for operations should be at least effective and better efficient. Then economy of informing is part of the model.

Ethics: Humans conduct operations not only in physical and physiological dimensions but also in social and spiritual dimensions, where different, frequently opposite laws operate. Thus, ethics plays a role, particularly in selecting purposes, means, mode of operations, and assessment criteria.

Peirce (1958), a pragmatist—the father of verifiability theory of the meaning—brings to our attention that, in operations, pure relevance is necessary, but it is only a precondition for further investigation. This is in contrast to Information Science, which studies methods of retrieving bibliographical information. In Decision Sciences, it facilitates a mathematical definition of the meaning (see Definition 5) and materiality (see Definitions 2 and 6) of changes in reality that are communicated by signals or messages associated with a non-zero amount of information, as viewed by Shannon and Weaver (1949). This makes communications informative for making decisions, whether by robots, artificial intelligence, or humans.

Praxiology: The study of the human conduct, defined by its fundamental triad: effectiveness, ethics, and efficiency (Gasparski, 1988).

Rationality: In informing for operations, one assumes that decision makers make rational or rule-following decisions, as defined by March (1994). However, we are limited to bounded rationality. Simon (1956) criticized the "model of perfect rationality" as unrealistic for three reasons: (1) an exhaustive search for all possible alternatives is impossible, (2) foresight of consequences is always limited, and (3) a system of values cannot be expressed completely.

Five years later, Kotarbinski (1961) did it in a more interesting and incisive way than Simon. Tsing (1993, p. 249), a Chinese philosopher of technology, commented, "*His [Kotarbinski's] approach is not inferior to Hume's problem*" with causality. Kotarbinski discovered and formulated the "*paradox of performability of the plan*" - "*If our action is guided by the model of perfect rationality we have to face the essential paradox: on the one hand, the performability of the plan must be ascertained before carrying it out, but on the other hand, the only definitive proof of performability of the plan is the performance of the plan.… We land in a predicament that nothing can be done. But not to act is also an action and should be forbidden too by the model of perfect rationality.*" Thus, pursuit of perfect rationality leads to perfect paralysis.

Contingency provision preventing irrational and undesirable decisions: Bounded rationality should not only be assumed but also enforced. There is no guarantee that normally rationally acting individuals will always act rationally or that a device will always function as expected. A well-designed model should incorporate preventive measures and contingency provisions against irrational, undesirable decisions and actions.

Choice uncertainty can be observed not only between near-simultaneous events but also in lesser dynamic situations, as insightfully described by Denning (2007). It needs arbitration: ethical where possible or automatic if the outcome is neutral.

All of the above are the points of departure for defining a comprehensive model of informing for operations. They may be summarized as follows:

> In operation, factors and their properties physically intrinsic (naturally belonging) to them acquire operational relevance (see Definitions 4a & b), meaning (see Definition 5), materiality (see Definition 2), availability, credibility, usability (fit for use), and/or usefulness (see Appendix to Chapter x, Definition 19)—usefulness only from the purpose and circumstances in the light of the adopted criterion of effectiveness, ethics, and/or efficiency. This occurs when a factor falls under a significant influence of the force field exerted by the will of competing decision makers, including the political and economic forces of the market in business, administrative, or military operations. In operations, no quality aspects intrinsic to factors or their use requirements are of any utility value on their own merit when not subject to the force field

exerted by the collaborative, competitive, and adversary objectified will of decision makers. It is analogous to the gravitational force fields of masses of matter.

With informing for operations, there is nothing that is not contextual with information, in contrast to the "Conceptual Model of Data Quality" by Wang and Strong (1996).

Introduction and Basic Definitions

There is a ***reality*** with objects, events, their properties, relationships, and acting subjects. ***Operations*** are processes conducted by at least semi-autonomously acting humans, their organizations, systems controlled numerically by programs, or artificial intelligence. They may include natural processes. Planned operations are triggered after an analysis of the situation. Operations are subject to the competitive, collaborative, and/or adversarial motivated will of participants. Will is a sufficient reason to act (Schopenhauer, 1974).

Elements of reality may facilitate or inhibit operations. A ***factor*** is anything that affects results of operations. Factors may be **in substance** or **in form**.

- ***Factors in substance*** must be transported and may entail the first three known Ms (material, machinery, and manpower), products, services, energy, or weapons and means in warfare, with their respective properties.
- **Factors in form** that can be communicated and/or transported are symbolic representations of reality. They entail methods, patterns, drawings, diagrams, schemas, data, information (e.g., location, time), and elements of knowledge - relationships among them, rules of reasoning and proceeding with all their **properties** - states of attributes or states of quality dimensions.

Factors may be **available** or **not-yet-available**. Unavailable factors are not part of the model:

Available factors in substance are considered **resources,** those in form - **data**.

Not-yet-available factors must still be acquired or delivered. They may be **routine** or **non-routine**.

- Routine factors are known by type and role; if in form, they constitute the routine communicated information.
- Non-routine factors are still unknown or unrecognised but of potential significance, such as a new invention, material, tool, or device. If in form, they constitute non-routine information, which is of a strategic nature that requires a separate assessment.

There is, however, an acute practical need to make a distinction between data as defined above and computer data values that are processed and stored in databases. No one is certain how the latter are related to the reality meant to be represented by the conventionally defined data values. Computer-processed-and-stored data values need a separate definition on their own merit independently of the former. This difference is ignored by practically all textbooks on MIS.

Computer processed and stored data values are merely symbolic representations of something determined and entered by or on behalf of the end user who originated them. Whether they are equal to the data values meant by the conventional definition depends entirely on the quality assurance in effect. It entails at least whether the computer data values have been

- **faithfully** (one to one or with sufficient accuracy and precision) **mapped** from the reality, as defined by Wand and Wang (1996),
- **not** willfully or inadvertently **distorted** during the data-entry process, and, subsequently,
- **not corrupted** by programmed procedures (e.g., *generally accepted accounting, assessment, or valuation procedures*) and/or database design and operations, as defined by Oliviera et al. (2005).

The above require careful planning, design, implementation, and monitoring of organizational procedures, including (internal and external) auditing, and their subsequent enforcement to bridge the gap that separates data values as conventionally defined from the actual computer data values in use.

Processes are partially ordered networks of state transitions or transformations of factors. The networks may be represented by graphs. Processes are natural or by design. Natural processes are **inert** or **evolving life processes**. They differ by type of input and requirements to occur.

1. ***Natural inert processes*** to be triggered and to occur require input factors subject to transformation and energy to occur.
2. ***Natural evolving processes*** require all of the above and the **information** necessary to trigger them and to control their evolution (e.g., *seeds, DNA*).
3. ***Processes by design*** require of all the above and the **information** about their design and/or the required by design means (e.g., *tools, equipment, etc.*), control, management, and work force. With the advances of technology and automation, the workforce is being gradually displaced by more and more sophisticated means of work and devices controlled numerically by programs or by artificial intelligence that extends the initial design of the processes. Processes by design that require human work are ***ergo-transformation processes*** [1].

In human-controlled processes, state transitions are oriented toward specific outcomes (not goals, objectives, or purposes, which are human categories and never intrinsic properties of processes). They form a ***graph structure***, as defined in the theory of sets. ***Business processes*** are also processes by design that transform factors from their initial states to their output states. They need **information** about their design to control or manage them. The latter two require continuous ***informing*** – flow of feedback and feed forward (control) information in operations.

Informing usually requires ***data and information processing*** – processes by design that transform factors from their initial states to their output states, which are limited to states of marks on the processed factors in substance – the carriers. The nature of marks is symbolic. Marks are factors in form for potential use, replication, and/or communication merely by their presence or absence, not to transform the carrying substance (e.g., *paper, magnetic tape, disk, or electrons with regard to their spin in quantum computing*).

Operations must be managed. ***Management*** plans, organizes, motivates, directs, supervises, monitors, and controls operations with the following distinctions:

- ***Routine management*** is charged with maintaining the current routine operations;
- ***Tactical management*** is charged with adjusting operations according to the perceived changes of reality, except the evaluation criteria, the chief executive decision maker, and the purpose;
- ***Strategic management*** determines the main purpose of operations, the criteria of effectiveness, ethics, and/or efficiency, and the chief executive decision maker.

These basic definitions provide the context within which a general model of informing for operations can be presented.

A General Model of Informing for Operations

In operations, ***managers*** are the driving force, the observing, participating, and interested decision makers with a **purpose,** as viewed by John Dewey (Magee, 2000) in his theory of inquiry. Here, purpose serves as the ***main point of reference***. Managers act within a **frame of reference** - circumstances to which the operations are subject. In social environments, selection of the purpose and means may and should be subject to ethical considerations.

Frame of reference is defined (Appendix, Definition 1) according to the decision-makers' knowledge, concepts, and wisdom. The frame consists of

- ***independent variables*** **(**e.g., *weather conditions*) that represent significant states of nature beyond decision-makers' control.
- ***dependant variables*** of significant materiality (see Definitions 2 and 3) that are under decision-makers' control (e.g., *to use or not to use* a toll road for trucking).
- an adopted ***criterion*** of effectiveness, ethics, and/or efficiency (e.g., *return on equity*).

One assumes that ***decision makers*** employ (see Appendix, Assumption 1)

- mainly rational and rule-following choices, as defined by March (1994),

- with **bounded rationality**,
    - as defined by Simon (1996) with regard to limitations of cognition, and
    - as proven by Kotarbinski (1997, pp. 189-201) from an opposite perspective. Perfect rationality is unattainable. (*If rigorously pursued, it leads to a logical paradox that precludes any action*);
- prevention of **irrational choices** that may undesirably change the situation (e.g., *unauthorized access or movement of nuclear warheads)*; and
- ethical, if possible, or automatic ***arbitration for resolving choice uncertainty***, as defined by Denning (2007). *(It is impossible to make an unambiguous choice between near-simultaneous events under a deadline*).

Measurability (see Appendix, Assumption 2) of the main purpose and the results of operations - the measure of the results is a function of the main purpose, the independent, and dependent variables.

Materiality of an entity (see Appendix, Definition 2) is the difference between the measure of results of operations conducted with and without the entity. Entities (e.g., *factors in substance, factors in form – data or information, tasks, variables, relationships, properties – states of qualities, or incremental changes of any of them*) are ***materially significant*** (see Appendix, Definition 3) if the absolute difference of the results of operations when conducted with and without them is not less than the ***threshold of significance*** – the minimal increment of materiality determined by the policy of decision makers.

The Staircase of Human Cognition

Human knowledge may manifest itself in many ways. ***Knowledge*** is what one knows or, broader, what society knows. It may be **in substance** (objectified in products, services), **in form** (data, routine information), and **formless**, undefined, not yet articulated (ideas, intuitions, instincts). In a computerized environment, ***knowledge*** is understood as symbolic representations such as data and relationships among them, rules of reasoning and proceeding, methods, patterns, topologies, etc., including sequences of state transitions of robots – programs, all of which may be stored in knowledge bases. Nevertheless, knowledge is a prerequisite for manufacturing products or rendering services; thus, they are manifestations of knowledge. By deconstructing, reconstructing, and replicating those products and services, one may reconstruct the objectified knowledge into its more conventional representation – knowledge in form, which may become embedded in artificial and/or biological neural nets. In popular usage, the latter is represented by the saying, "He knows how to play the piano well."

Anything that can be subject to **operational replicability** with **results at a statistically significant level of confidence** is part of our ***scientific knowledge – hard-science;*** otherwise it may be subject to speculation, hypothesis, etc. Some of the latter may also be part of commonly shared meanings and beliefs, which belong to human culture, not science. They may also be the subject of inquiry.

Reality, operations, factors, and our knowledge about them are subject to changes. Thus, a system that monitors the changing reality must be established to maintain current what is known. In routine operations, collection of values from the monitored reality takes place for all the known factors of significant impact on operations. The available representations - data - describe a relatively static picture of routine operations whose quasi-equilibrium will eventually be disturbed. Data are used at all three levels of management: routine, tactical, and strategic. From the viewpoint of routine and tactical management of operations, all observed, measured, or communicated ***representations of changes and/or distinctions*** are either

- **operationally irrelevant** (do not pertain to the considered model).
- **routine data.** They are operationally relevant (see Definitions 4a and 4b) but overlap the already known being embedded in formal or only mental models of the situation, do not change the status quo, and are the entropy of the system; they are of no operational meaning and are associated with a <u>zero</u> amount of information, as defined by Shannon and Weaver (1949).
- **routine information.** They are operationally relevant (see Definition 4) and of operational meaning (see Definition 5). Then, they trigger a state transition of the model, they change its entropy, and they are always associated with a <u>non-zero</u> amount of information with some subsequent consequences

within the situation and its model. Routine and tactical management deals with routine information.

Symbolic representations obtained from monitoring reality about the ***non-routine factors*** that may impact operations should be considered separately. They are mainly the realm of strategic management and decision making. **Non-routine information values and elements of knowledge,** after being acquired and recognized as valid, if only operationally relevant, of operational meaning, and significantly material, always **qualitatively and quantitatively change the entire decision situation** because they represent factors not yet accounted for.

All of the above represent directly or indirectly the decision-maker's knowledge about the situation. As far as possible, knowledge is presented here in an operationalized manner. It facilitates its codification and storage in knowledge bases. Human actions, however, are based on the available data, knowledge concepts, and wisdom, as well as on emotions, which frequently prevail. Modeling of operations should account for all of them. Selection of purposes, means, mode of operations, and assessment criteria of results should be subject to ***wisdom***. Modeling is more art than science but is always a game of politics. Manifestations of knowledge are summarized in Table 1. ***Concepts*** are insights into potential solution to the question of how to act. In summary, **information**, **data**, **knowledge**, **concepts**, and **wisdom** are ***steps in the staircase of human cognition***. More about units of cognition in a semantic ladder is presented by Targowski (2003).

Table 1: Manifestations of human knowledge

H U M A N K N O W L E D G E as representation of reality about objects, events, their identifiers and properties, relations among them, and rules of procedure in reasoning and proceeding				
Already objectified - in substance		In form – represented symbolically		Formless – not yet articulated
Products	Services	Available - Data	Not-yet-available – to be acquired routine information	Non-routine information – to be recognized & researched
To be deconstructed and reconstructed, if representation in form is not available	To be deconstructed and replicated, if representation in form is not available	About the given, known, available, assumed true factors; never change the decision situation, if communicated, are associated with zero amount of information and used at all levels of management	About changes of known operation factors that usually cause only quantitative changes of results; if communicated associated, are with a non-zero amount of information and used by routine and tactical management	Ideas, intuitions, instincts about still unknown factors; if significant, they qualitatively and quantitatively change decision situations; if communicated, they are associated with a non-zero amount of in-formation and used at the by strategic management

What one does not know, one tries to learn (observe, acquire). New facts, properties, relationships, and rules of procedure, after they have been recognized as valid, at least acceptable and actionable, are added to what was known before. Thus grows the body of knowledge of individuals, organizations, and societies. It also implies that data are always derived from information, not vice versa, as most authors of MIS textbooks present. Observed or communicated information after it has been internalized by being recognized and accepted as potentially actionable factors in form are becoming the decision-makers' ***data*** that are used for modifying decision-situation models.

Changes in Decision Situations

Components of decision-making situations, when described and defined, entail (1) possible states of the independent variables, (2) potential choices or decision options - dependent variables, (3) projected outcomes for the respective pairs of the above, (4) utility values assigned to outcomes by a utility function, (5) evaluation criteria of the outcomes, (6) decision makers, and, finally, (7) the main purpose of operations. They are listed in ascending order of the expected extent of pervasiveness of their changes.

Outcome is an array of states of significant aspects of reality. Decision makers project their states as the consequence of their decisions and specific states of nature. Outcomes are rarely simple variables. They may represent the final cost, a picture of a scene after an accident, a village after a tornado hit, or a field after a battle.

Decision-situation specification matrix (see Table 2) is built based on the available knowledge. At first, it offers a static picture. The monitored changing reality (the system and its environment), however, requires continuous adjusting of at least some components of the model. The type, number, and degree of the changes is induced not only by the changing environment but also by the decision maker, who adjusts the way he/she views the situation and reacts in response. A decision-situation matrix serves here as the lens through which one tracks the changes of factors, their operational meaning (see Definition 5), and materiality (see Definition 6).

Changes of independent variables and probabilities of their states are viewed as the difference between their respective current (') and previous (") states caused by observed or communicated changes of some aspects of reality. They invariably change the affected outcome, its utility, and the results of operations. A ***utility function*** assigns utility values to the respective differences with regard to each aspect of reality. Decision makers may also change their tactic (select different decision options) from the previous to the current one. Together, they change the total outcome equal to the difference between the two arrays - the current outcome $\mathbf{O_c}$ and the previous outcome $\mathbf{O_p}$. The difference $\mathbf{O_c - O_p}$ is the ***operational meaning*** (see Appendix, Definition 5) of an observed or communicated factor's change, as viewed by Peirce [14], the father of verifiability theory of the meaning, while its subsequent ***operational materiality*** (see Appendix, Definitions 2 and 6) is the difference between materiality of the current outcome and materiality of the previous outcome.

Table 2: Decision situation matrix

j[1...m]/ /i[1..n]	p_1	p_2	…	probabilities$_j$	…	p_{m-1}	p_m
	Sn_1	Sn_2	…	states$_i$	…	sn_{m-1}	sn_m
D_1	$u(o_{1,1})$	$u(o_{1,2})$	…	…	…	$u(o_{1,m-1})$	$u(o_{1,m})$
D_2 …	$u(o_{2,1})$ …	$u(o_{2,2})$ …	…	…	…	$u(o_{2,m-1})$ …	$u(o_{2,m})$ …
decisions$_i$	…	Utility values of outcomes o_{ij}: $u(o_{ij})$, where u – a utility function					…
…	…						…
D_{n-1}	$u(o_{n-1,1})$	$u(o_{n-1,2})$	…	…	…	$u(o_{n-1,m-1})$	$u(o_{n-1,m})$
D_n	$u(o_{n,1})$	$u(o_{n,2})$	…	…	…	$u(o_{n,m-1})$	$u(o_{n,m})$

For measurements, physics uses a well-defined point and frame of reference and a yardstick. They constitute a selected perspective for viewing reality. Nietzsche's (2008) perspectivism denies an all-inclusive perspective that contains all other perspectives and makes reality available as it is in itself.

The presented approach adopts the ***postulate of teleological perspectivism and relativity of assessments*** (see Appendix, Assumption 3). Assessments of all aspects of reality except the physical constants are subject to the

- teleological perspectivism, as defined by Nietzsche [15], and
- restricted relativity, as defined by Einstein [4 p. 13], where aspects are assessed equally unless purpose and frame of reference do change.

Nevertheless, when a change occurs, it changes how even the physically identical entities are viewed differently by decision makers.

For decision makers, an observation or a communication about a factor that is relevant to the model symbolically represents an aspect of reality that

- matches the state of the model, thus does not change it or its entropy and conveys a zero amount of information, because it equals the already given, available is a ***datum***.
- does not match the state of the model, thus changes it and its entropy and conveys a non-zero amount of information is a communicated ***operationally meaningful information***.

Reality and the discussed changes of decision situations are always discrete, and so is information and digital computing.

Quantum Nature of Information

In rigorous studies, the smallest distinguishable element subject to inquiry must be defined. The emergence of nanotechnology, quantum computing, molecular bioengineering, and so on indicates our will to reach down to the naturally elementary. It may be an elementary act of exchange of goods in economy, transaction in business, movement of a robot, human action, change of the spin of electron in quantum computing, or elementary behavior of a particle down to the submicroscopic systems of the minimum observable. With new technologies, the size of significant changes decreases precipitously.

The low limits of changes are usually determined by the state of measurement technology (methods, tools, and means). Observations, measurements, or communications that one to one map changes of reality are subject to the perspectivism and relativity of assessments of their impact on operations; they are always discrete symbolic representations for storing, communicating, and acting, as are also the results of digital computing. Changes may impact the entire model of operations, the decisions made, and their implementation. One always assumes they are of interest if they cause a significant change in the measure of the results of operations with regard to their purpose in the light of the adopted criterion of assessment. These changes, and their smallest increments, cannot be less than the smallest amount of action known in physics – the Planck's constant (2007). So it is with factors in form represented by signals, messages, communications, and the amount of information associated with them, as defined by Shannon and Weaver (1949). This is a universal principle; hence, it always applies except for the physical constants.

The First Principia of Informing for Operations

The qualitatively presented model allows summarizing the first universal principles identified by studying the nature of informing for operations viewed through the lens of decision making, particularly those principles that operate as fundamental laws – principia. They may apply to factors in substance, factors in form, their properties, and the decision variables that represent them.

Components of the proposed framework and the model for research in informing are anchored in formal definitions, basic assumptions, logical principles, laws of nature, and economy. The validity of a general framework or model cannot be directly proven, although it can be tested, disproved, and refuted, as stated by Hume and restated by Popper in his *Logic of Scientific Discovery* (1959) (Magee, 2000, p. 115 and p. 223). They do not require empirical validation except for coming up with examples to the contrary. Then a revision is unavoidable. The proposed model and framework, however, needs to be discussed, challenged, and criticized by the community of actual and potential researchers in informing; their approval is necessary for broader use. If the model remains unchallenged, it qualifies as the results of basic research, in contrast to applied research with always situation-specific results.

For the universal principles—the principia—no exceptions are in sight. Applicability and validity of most of them reaches beyond operations conducted or only controlled by humans. Some of them apply equally, even to activities and state transitions in living entities. Hence, they should be of priority in research considerations, whether basic or applied, and helpful for advanced research pursuing results of lasting validity.

I. Teleological Perspectivism and Relativity

Without a point and frame of reference, one is lost. ***Teleological perspectivism*** (as defined by Nietzsche, 2008) ***and relativity*** (as defined by Einstein, 1961) ***of observations, measurements, and assessments*** apply to informing, operations, operations management, and decision sciences of activities controlled by humans when information is a significant factor. In human-controlled operations, assessments are determined by the purpose and significant circumstances according to the selected criteria of effectiveness and/or efficiency of operations under the assumption that decision makers employ a bounded rational and ethical approach to decision making.

II. Quantum Nature of Information and Informing

Ultimately, there is no continuity. ***Operation factors,*** whether in substance or in form (information), ***are of quantum nature***. They are discrete and granular, including changes of their properties. At the lowest end of their amount, a change cannot be less than the elementary amount of action – the Planck's constant (2007). With the emergence of nano-technology, quantum computing, and molecular bioengineering, we reach down to the naturally elementary. Otherwise, it may be an act of exchange of goods in economy, transaction in business, movement of a robot, human action, change of the direction of the spin of an electron in quantum computing, etc. With new technologies, the size of significant changes decreases precipitously.

III. Sufficient Conditions for Informing Resonance

Between informing entities and entities informed, informing occurs by communicating signals that represent differing corresponding states that are within similar ranges when by resonance equalization and/or synchronization of some states takes place.

There are ***universally necessary conditions for effective informing resonance are:***

1. There must be an initial difference in states between informing entities and entities informed. In communication theory (Shannon & Weaver, 1949) the difference is measured by entropy.
2. Some of those states must be corresponding or equivalent states within similar ranges of states to make resonance possible between them. The concept of informing resonance was proposed by Gill (2008), but applied only to human mental models. It is a universal phenomenon whether we deal with mechanical, electromagnetic, molecular, or mental entities and their models. When entities resonate, they communicate, not necessarily effectively yet.
3. If equalization and/or synchronization of states occurred, a communication took place, a state transition within the entity informed (its physical, formal, or mental model) has been

triggered, the entropy of the communication system changed, thus the received communication has been recognized and was not available or known before, otherwise it overlaps with what is already available to the entity informed.

4. However to become operationally effective, the received communication must be internalized as situation-specifically, actually or potentially actionable data and/or elements of knowledge qualified to update databases and knowledge bases, otherwise the communication is irrelevant. Nevertheless, it might have been relevant, but was only handled otherwise. Thus for informing to be effective the communication must resonate with the receiving, decision-making, and action executing mechanisms. They have their human equivalents of those who as a single individual or, with division of labor, those individuals who were in charge of receiving the communication, making decision, and executing it, as it occurs in complex organizations. If a communication fails to resonate at any of the intermediary stages of operational informing, informing is ineffective.

IV. The Alpha and Omega of Informing: its Trans- and Interdisciplinary Nature

The entry and exit points and the moments when the information process begins and terminates unambiguously define the boundaries and scope of informing . The entry point where and the moment when the informing process begins are with the informing entity – the observed source or the communicator. This may be a fragment of reality that has been perceived, observed, measured, counted, weighted, etc. or a signal emitted by the communicator or disseminator in active informing by design. The ***exit point where and the moment*** when the informing process terminates are with the entity informed, in which the observation or communication triggers a state transition after the information has been internalized (recognized and accepted) as potentially **actionable datum**.

Any ***subsequent state transition triggered*** within or by the entity informed belongs to the subject domain of the affected operations and the intersecting discipline to which they are subject. In routine operations, within that discipline, not within informing, are defined as the main purpose (the main point of reference) of these state transitions, a yardstick to measure it, the frame of reference (circumstances) of them, and the assessment criteria.

These points and moments delineate the ***boundaries of informing*** and the other intersecting disciplines; hence, informing is always **interdisciplinary**. For instance, in research for extension of knowledge, informing always intersects with one or more disciplines that apply to its source(s). In operations, informing always intersects with two or more disciplines that apply to its source(s) – informing entity and the operations conducted by the entity(s) informed. Thus, on the one hand, informing always operates in an **interdisciplinary** context, while on the other hand, informing literally permeates all disciplines; hence, it is a **transdisciplinary** field of inquiry. Nevertheless, informing also stands on its own merit as a **separate field of inquiry**.

V. Inherent to Informing Challenges to Quality

Observations, measurements, and communications are vulnerable to random errors and quality problems inherent to informing: bias and distortions. The ***ultimate*** intrinsic (naturally belonging to it) ***purpose of informing***, whether acknowledged or not, is to extend one's control over one's environment, whether physical or social. Among **living entities*, bias*** occurs with (a) communications received due to **ignorance** and **wishful thinking** of the one informed, and (b) communications sent by design due to **ignorance** and **purpose** of the communicator.

Entities informed should be interested in knowing how a considered information differs, how distant it is from the **valid information,** which serves here as the main point of reference for the following cases:

- ***Disinformation*** is designed by the communicator to deceive. (For deception, *perfect disinformation* - the exact reverse of valid information cannot be used. Effective disinformation must contain valid elements to suggest or imply credibility.) ***Misinformation*** misrepresents reality,
    - on the one hand, due to malfunctioning of receptors (e.g., *instruments, eyesight, hearing,* etc), ignorance (e.g., *misinterpreted terminology, definition, language*), and unwarranted wishful expectations by the one informed, and,

  - on the other hand, unintentionally by ignorance or on purpose by veiled design is biased (custom tailored, articulated) by the communicator to serve the current purpose of the communication sent.
- ***Valid information*** (the rarest of all) maps faithfully one-to-one reality into the communicated representation, as defined by Wand and Wang (1996).

This applies to competitive environments. Within willing alliances and organizations formed for higher competitiveness, the bias attributed to purpose is usually limited but not eliminated. Even organized crime enforces the rule, "*Never lie to your boss.*" The exceptional nature of valid information necessitates creation of institutions and services that are based on trust by serving credible information. Misinformation and disinformation require careful design of counter measures (e.g., d*ouble checking*) and contingency provisions (*never fully trust a single source*), including intelligence and counter intelligence.

From the perspective of the informing entity – communicator – effective communication is of main concern, how the actual results differ from the intended ones. Here one deals with even a wider-than-above spectrum of miscommunications:

- ***Perfect communication*** – 100% effective (e.g., *all marketing targets ordered from us*), which serves here as the main point of reference;
- A wide range of ***effective communications*** within the range of effectiveness between less then 100% and more than 0%;
- ***Miscommunication*** within the range of effectiveness between 0% and more than 100% (e.g., *most targets ordered from our competition*);
- ***Discommunication*** - an abstract limit, where the result is the exact reverse of what was intended – a perfect failure (e.g., *a communication in response to which no one ordered from our company and all targests ordered from competition*).

VI. Futile Quest for a Direct Compound Metric of Quality

Direct compound metrics of any group of factors' qualities are objectively impossible and useless. By the law of teleological perspectivism and relativity, all assessments, including assessments of qualities of factors, are always situation-specific, hence

- neither **universal**
- nor of equal **materiality.**

With not many exceptions, **improvements to qualities do not monotonically improve** the results of operations due to the law of **diminishing returns** (2007). A direct compound metric of any group of properties must be arbitrary, not objective, and is impossible and useless. Nevertheless, it is possible to test how changes of single properties impact results of operations.

VII. Taxonomy and Ordering of Quality Requirements Related to Use of Data

When viewed from the teleological perspective of operations through the lens of decision making, the entire universe of quality requirements related to use of factors in form is subject to a universal disjoint taxonomy and ordering.

They all are situation specific and affect operations directly or only indirectly. The decision-situation matrix identifies the **direct** factors, which may be complex functions of **indirect** factors affecting the direct ones. Any of them must first meet all the necessary use requirements that make them usable. Necessary use requirements are, by default, prerequisites for further examination of the remaining requirements of the affected factor. For the sake of economy of examination, they should be examined in the sequence determined by their decreasing strength as prerequisites measured by the number of necessary use requirements that need not be tested in case the tested one is not met. It only partially (asymmetric, transitive) orders necessary requirements, because some of them may be of equal strengths. In such a situation, one should test them in a sequence determined by the increasing difficulty of their testing – test the easiest first; thus, there is nearly always a choice available. As such, in most cases, it satisfies the axiom of choice (2008), as required by the theory of sets for well-ordered sets.

The necessary use requirements can be further subdivided into primary and secondary ones. Again, the primary ones can be subdivided into universally and other primary situation-specific necessary use requirements. Both should be tested, beginning with the universal one. Such testing identifies each examined factor in form as

1. operationally recognized or not ;
2. the recognized into operationally relevant or irrelevant
3. the relevant into those of operational meaning or not
4. the one of operational meaning into those of operational significant materiality (see Definition 6) or insignificant;
5. the one of significant operationally materiality into those operationally timely available or not;
6. the timely available into on-site available or not;
7. the one on-site available into actionably credible to act or not;
8. the one actionably credible into those that meet all other situation-specific primary necessary use requirements or not.

From the perspective of the conducted operations, factors in form that meet all the primary necessary use requirements are ***effectively usable***, otherwise ***useless***. The ***effectively usable factors*** that also meet the secondary use requirements of ethical and/or economic nature are ***ethically*** and/or ***efficiently usable.*** If the purpose of operations is measurable, all of the usable factors can be partially (asymmetric, transitive) ordered or ranked by their **materiality** or **efficiency of their use**, as applicable.

Effectively, ethically, and/or efficiently usable factors in form, when **operationally complete** for specific tasks, are ***actionable factors***. If the actionable factors are actually engaged in the conducted operations, they are ***directly effectively, ethically,*** and/or ***efficiently useful***; otherwise they are ***factors in waiting***, hence ***indirectly useful***.

The indirect ones may be additionally partially ordered by the distance from which they affect the direct factors measured by the number of the intermediary factors plus one. Thus, they may be indirect factors of the first, second, and subsequent orders. The necessary direct and indirect factors, their required quality aspects, and properties of their use in operations are partially ordered by the factors' materiality of the direct factors.

VIII. Materiality: The Fundamental, Central, and Most Pervasive Use Requirement

Materiality is a fundamental, central, and the most pervasive requirement related to use of all factors. In operations, it is

- **fundamental** – because it is the only necessary use requirement that provides each factor with a sufficient reason to be considered in operations.
- **central –** because it is indispensable for all considerations about effectiveness and efficiency of operations. It ranks or orders all factors.
- **the most pervasive** use requirement – because it determines the materiality of the remaining necessary quality requirements of the same factor, the materiality of its necessary companion factors in tasks, and, to a lesser degree, affects the materiality of other factors related to it.

Properties acquire their materiality from the purpose and circumstances of operations. Factors acquire materiality from their significantly material properties. Materiality of a factor limits materiality of its remaining properties. Properties of an insignificant factor are insignificant, too, unless any of them acquires significant materiality on its own merit and lends it to the attributing factor.

IX. Uncertain Usability of Factors Degrades Decision Situations

Uncertain usability of factors degrades decision situations. If usability is

- **certain**, the decision maker deals with a **deterministic situation** in the area affected by the factor.
- **only probable** (the most likely case), the decision maker deals with a **stochastic situation** to the same extent as above.
- **not usable**, (e.g., *not timely available or not actionable credible*), the decision maker **games** to the same extent, even when operations are not triggered (*threats ignored*).

X. Dichotomy of the Available and Not-Yet-Available Factors in Form

The ***dichotomous*** (twofold) ***nature of the available and not-yet-available factors in form - of data*** (the given) ***and information*** (the communicated or to-be-communicated change) refutes the existing fuzziness of interchangeable use of both terms. In decision situations, they always are **disjoint** sets of entities.

- **Replacements of any available factor** in substance or available factors in form such as data, or received symbolic representations of reality of a zero amount of information **never change** decision situations.
- **Quantitative change of any known factor** in substance or routine information that communicates a quantitative change of known symbolic representations of reality – factors in form of a non-zero amount of information – **only quantitatively change** decision situations unless the quantitative change exceeds the acceptable limits or reaches a critical point, causing qualitative changes of decision situations (realm of operational and tactical management).
- **Unrecognised significantly material factors** in substance or **non-routine information** about significant not-yet-recognized elements of reality **always qualitatively and quantitatively change** decision situations. They are the realms of strategic management.

How the Principia Might Impact Research into Informing

The presented conceptual model is a system of basic assumptions, formal definitions, laws in science, and logical inferences. As such, it cannot be proven directly to represent reality, but it can be tested, disproved, or refuted, as stated by Hume and restated by Popper in his Logic of Scientific Discovery (Magee, 2000). Some express general doubts about the universality of these principia because the universality of some assumptions has not yet been proven. Let us not forget that even causality cannot be empirically proven, but it is assumed successfully. In science, such proofs are impossible, but any of the principia can be disproved by demonstrating an exception to the contrary, which has not yet happened. The model should be discussed, challenged, and criticized by the community of interested researchers, but not by expressing general, not specific doubts.

The identified principia apply equally to factors in substance and factors in form, such as data, information, and decision variables that represent them. There seem to be no exceptions in sight. Some of the principia apply at least partially to activities and state transitions occurring with living entities, even individual living cells, not only operations controlled by humans. They deserve careful consideration in research, whether basic or applied, and in doctoral dissertations. If they remain unchallenged, they will stand as the results of basic, in contrast to applied research, which is always situation-specific. This first attempt assumes a single main purpose with no conflicting requirements and constraints imposed on decision makers. This fact offers research opportunities for expanding and refining the model to accommodate more complex cases. Nevertheless, strongly conflicting purposes, hence conflicting interests, must be resolved at the strategic level of management, not within informing.

Formalization of definitions opens the door for in-depth research by modelling and simulating informing for operations as state transitions caused by informing affect results. Simulations will facilitate the quest for discovering more complex quantitative dependencies and likely the discovery of other principles. Based on a formal model, research results obtained from simulations conducted under rigorously controlled conditions promise results of a lasting validity versus empirical studies conducted without such a model.

The principia offer a broad general frame of reference for research into informing for operations that compel researchers to focus their attention on defining observable and measurable purposes to serve as the main point of reference for assessing the impact of informing on operations from the perspective of not an objective, but participating, interested observer - chief executive decision maker, as defined by Dewey (Magee, 2000, p. 293) to prevent pursuing loosely articulated hypotheses. The principia

1. remind researchers that informing as computing ultimately are of quantum nature,
2. separate the subject of informing from the subjects of its intersecting disciplines,

3. remind that valid information is the exception and misinformation is the rule,
4. identify necessary and sufficient operational conditions for usability and usefulness of factors,
5. demonstrate how uncertain usability gradually degrades decision-situation models,
6. deny the possibility of objective compound direct metrics of quality with groups of aspects attributed to factors in form or factors in substance,
7. universally class and order quality requirements related to use of data/information,
8. focus researchers on significant materiality of information as the fundamental, central, and most pervasive use requirement for operations in distinction for extension of knowledge,
9. illustrate how differently data and information affect decision situations.

Even in survey-based empirical research, the distinction of necessary primary and secondary use requirements and their always contextual nature facilitates articulation of pointed well-defined questions that increase reliability of the answers provided by respondents. There are ample examples of such studies with inconclusive, even contradictory results. Three blinded cases of survey-based statistical studies of information quality and its impact on operations when viewed from the teleological perspective reveal the peril of not observing at least some of these principia (Gackowski, 2009).

1. More realistic survey instruments can be developed with properly organized, focused questions asked within their task-specific context.

2. Questions about necessary requirements should be asked first in the sequence by their diminishing strength as prerequisites.

3. Binary questions cannot be asked and answered on a 5- or 11-point scale.

4. Completeness cannot be tested if usability of all necessary task-specific components has not yet been ascertained.

5. Contributing factors should be tested only if a direct requirement has not been met, not side by side.

6. Does the impact of any necessary requirements require any empirical confirmation?
7. Nevertheless, there is room for empirical survey-based statistical studies about individual preferences.

The above observations are presented to explain why so many empirical studies end with inconclusive results and why researchers need and to foster better understanding of the phenomena and development of more realistic survey instruments (Gackowski, 2008a, 2008b, 2009).

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Appendix – Formal Definitions and Formulas

Definition 0: ***Managers*** are the driving force. They are the observing, participating, and interested decision makers with a **purpose P,** as viewed by John Dewey (Magee, 2000) in his theory of inquiry; **purpose** serves as the ***main point of reference***. Managers act within a specific **frame of reference** (circumstances the operations are subject to).

Definition 1: ***Frame of reference*** is based on the available knowledge, concepts, and wisdom. It consists of

- ***SN*** – a set of variables (**sn є SN)** that represent significant states of nature and are **beyond control** of decision makers - ***independent variables*** such as *weather conditions*;

- ***D*** – a set of ***dependant variables*** **(d ϵ D)** of significant materiality that are **under** decision makers' **control,** such as *to use or not to use a toll road for trucking*;
- an adopted ***criterion*** of effectiveness, ethics, and/or efficiency.

<u>Assumption 1</u>: Decision makers employ

- mainly **rational** and **rule-following choices**, as defined by March (1994);
- with **bounded rationality**
  - as defined by Simon (1956) with regard to limitations of cognition, and
  - as proven by Kotarbinski (1961, pp. 189-201) from the opposite perspective that perfect rationality is unattainable (*if rigorously pursued, it leads to a logical paradox that precludes any action*);
- **prevention** of **irrational choices** that may qualitatively change the situation; and
- ethical, if possible, or **automatic arbitration** for resolving **choice uncertainty** in dynamic situations, as defined by Denning (2007). (*It is impossible to make an unambiguous choice between near-simultaneous events under a deadline.*)

<u>Assumption 2</u>: ***Measurability*** of the main purpose **P** and the results of operations denoted **RO**. The measure of the results denoted $\mathbf{M_{RO}}$ is a function of the main purpose **P**, the sets **SN** and **D**, formally, $M_{RO} = M_{RO}(P, D, SN)$.

<u>Assumptions 3:</u> ***Postulate of teleological perspectivism and relativity of assessments***. Assessments of all aspects of quality are subject to the

- teleological perspectivism as defined by Nietzsche (2007) and
- restricted relativity as defined by Einstein (1961, p. 13).

Aspects are assessed equally unless purpose and frame of reference change. Nevertheless, when a change occurs, it changes how even the physically identical entities are viewed differently by decision makers.

<u>Definition 2:</u> ***Materiality M(e) of entity e ϵ E*** is measured by the difference in the measure of results $\mathbf{M_{RO}}$, when operations are conducted with and without the entity e, formally

$$M(e) = \mathbf{M_{RO}(E) - M_{RO}(E - e)}$$

<u>**Definition 3**</u>: ***E*** is a set of ***materially significant entities*** **e ϵ E** {

- factors in substance or in form (here, mainly **data** and **information** items) **f ϵ F**
- tasks **t ϵ T**
- variables **v ϵ V**
- relationships among them **r(e', e") ϵ R(E', E")**
- qualities **q(e) ϵ Q(E)**
- properties - states of qualities **s(q(e)) ϵ S(Q(E))**, or
- incremental changes of their states **Δs(q(e)) = s'(q(e)) – s"(q(e))**},

if the absolute | | difference of the results of operations $\mathbf{M_{RO}}$ when conducted with and without them is for each (ϖ) not less than the ***threshold of significance*** – the minimal increment $\mathbf{S_{min}(\Delta M_{RO})}$ of materiality **M(e)** determined by the policy of the decision maker, formally

$$\varpi\ [\,|M_{RO}(E) - M_{RO}(E - e)| \geq S_{min}(\Delta M_{RO})]\ \text{for all } e \in E\text{, or}$$

$$\varpi\ [\,|M(e)| \geq S_{min}(\Delta M_{RO})]\ \text{for all } e \in E$$

Formally: If a recognized entity $\mathbf{e_x}$ matches some (V) elements **f** of the actual significant operational factors f ϵ F(T), it is operationally relevant. The latter is the union ⋃ of clusters of factors **cf(t)** necessary for all elementary tasks t ϵ T (closed set of all tasks) in the network, into which operations O can be decomposed as practiced with PERT (Moder et al., 1983): $F_O(T) = cf(t_1) \cup cf(t_2) \ldots \cup cf(t_n) = \bigcup cf(t)$ for all t ϵ T, and n = cardinality of ||T||.

<u>**Definition 4a**</u>: **IF V($\mathbf{e_x}$ = f)** for some f **0** $F_O(T)$, **THEN** the **recognized** entity $\mathbf{e_x}$ is ***situation-specific operationally relevant*** and becomes a **recognized** and **relevant** operational **factor** $\mathbf{f_x}$ subject to further examination.

With a formal model of operations, one may define operational relevance in relation to its operational variables **ov**.

<u>**Definition 4b**</u>: **IF V($\mathbf{e_x}$ = ov)** for some ov ϵ OV, **THEN** the recognized entity $\mathbf{e_x}$ is ***situation-specific operationally relevant*** and becomes a **recognized** and **relevant** operational **variable** $\mathbf{ov_x}$ subject to further examination.

Formally: If the examined relevant factor $\mathbf{f_x}$ makes a non-zero difference or a non-empty $\boldsymbol{\Theta}$ set of differences $\mathbf{O_M(f_x)}$ between the current and previous outcomes denoted $\mathbf{O_c(f_x)}$ and $\mathbf{O_p}$ of the operations model $\mathbf{O_M}$, then it is a factor $\mathbf{f_m}$ of a ***situation-specific operational meaning***.

__Definition 5__: **IF $\mathbf{O_M(f_x) = [O_c(f_x) - O_p] \neq 0}$ or not an empty set $\boldsymbol{\Theta}$, THEN** the examined factor $\mathbf{f_x = f_m}$ is of ***situation-specific operational meaning***; it becomes an operationally **recognized, relevant,** and **meaningful factor**. The utility function **u** assigns utility values to the respective outcomes in conformance with Assumption 3.

__Definition 6__: $\mathbf{M_{RO}(O_C - O_P) = M_{RO}(O_C) - M_{RO}(O_P)}$

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Chapter 11

Informing Processes, Risks, Evaluation of the Risk of Misinforming

Dimitar Christozov, Stefanka Chukova & Plamen Mateev

Introduction

The value of information can be measured by its impact on the receiver, often referred to as the *client* in informing contexts. This impact reflects on whether and how the client utilizes the information in acquiring operational knowledge, i.e., knowledge that will affect client's decision making processes and his overall behavior. Building operational knowledge through communication is the objective of every informing process.

There are many factors affecting the success of an informing process (see for example Gackowski 2006a and 2006b). The failures of such a process can be divided into four categories:

1. *Failure of Transmission*: Failures resulting from the fact that the client is not able to get the message send by the sender or s/he is unable to decode it. These are purely technical failures and will not be considered here.
2. *Failure to Attend*: The user fails to attend the channel being used by the sender.
3. *Failure to Impact*: The client gets the message, but disregards it or already possesses the information provided, meaning a connection is made but does not lead to any increase in operational knowledge.
4. *Misinforming*: The client gets the message and accepts the information provided, but the generated operational knowledge differs from the knowledge the sender intended to form i.e., it generates misleading knowledge.

In this chapter, we assume that the senders provide true and fair information, according to the best of their knowledge. We will not discuss the case of disinforming, i.e., purposely providing misleading information. Instead, our focus is on the measuring of the success of an informing process, emphasizing the last category of failures, i.e., failures caused by misinforming. We also consider the following questions: What are the reasons for the failures caused by misinforming? Is it possible to measure the risk of misinforming? If it is possible, then how can we measure this risk?

We understand misinforming as an incorrect interpretation on behalf of the client of otherwise correct information provided by the sender. Misinforming is due to the existing asymmetry in the background knowledge and preliminary information available to the sender and the client. This asymmetry works in two directions. On one hand, the sender knows the intended meaning of the "information" being conveyed, but he has limited knowledge regarding the client's objectives with respect to the use of this information. The client, meanwhile, interprets the message according to his or her knowledge and objectives, but has limited knowledge of the sender's intended meaning. From this viewpoint, assessment of the risk of misinforming itself provides learning opportunity to both parties and may offer some ideas on how to improve the informing process between them.

The next section of the chapter provides the background and the framework for developing models for quantifying the risk of misinforming. In section three, we present several models for evaluating the risk of misinforming. In the fourth section we illustrate these models by an empirical study.

Background

A Successful Informing Process

Definition 1: We consider "a success" in an informing process in several levels, where a higher level includes all of its lower levels. The levels correspond to the categories of failures described above:

Level 1: An informing process is successful if the message created by the sender is successfully transmitted to the client.

Level 2: The process is successful, if the client reads and attempts to understand the transmitted message.

Level 3: The process is successful, if the client does not ignore or already possess the information included in the message, but rather accepts and adopts the information encoded in it.

Level 4: The process is successful, if the acquired knowledge coincides with the information the sender intended to provide to the client. Also this level of success addresses the fact that the objectives of the client in acquiring this information meet the intention (purpose) of the sender in providing it.

The risks associated with any of these levels of success are as follows:

1. The risks on the first level are associated with any technical problems in the communication channel, e.g., technical failures or noise. Other risks include encoding-decoding problems and linguistic problems. In any case there is no informing at all or informing requires extra activities.
2. The risks on the second level relate to a possible distraction of the client, meaning that the client is not paying attention to the communications channel or he/she is ignoring the fact that the channel is used. Once again, both cases lead to a failure to inform.
3. The failures on the third level are either caused by complete overlap with pre-existing knowledge or by trust/credibility problems. In either case, the client's knowledge state does not change, meaning that he or she is not informed.
4. The risks on the fourth level are the risks of misinforming. The obtained knowledge differs from the knowledge the sender intended to form and may mislead the client in her/his decision making.

Information Asymmetry as a Source of Misinforming

In business transactions, the information asymmetry occurs when one of the parties involved in the transaction has more or better information than the other one. In economics, the imbalance is most commonly presented in describing markets, referred to as markets with asymmetrical information. In these markets, the seller typically knows more about the product than the buyer. It is also possible, however, for the reverse to be true. Examples, where the seller usually has better information than the buyer, might include used-car salespersons, stockbrokers, real estate and life insurance. An example where the buyer may be better informed than the seller is a situation where a buyer purchases insurance for a property with hidden problems.

The informational misbalance was described for the first time by Kenneth J. Arrow (1963), who introduced it as a "moral hazard". Later, George Akerlof (1970) used the term asymmetric information, noticing that, in a market with asymmetrical information, the average value of the commodity tends to go down, even for commodities with perfect quality. Moreover, he pointed out that it is possible for such a market to decay to the point of non-existence.

In general, the purpose of an informing process is to provide information from a better informed party (usually the sender) to a less informed party (usually the client). If the client is as well informed as the sender, no informing occurs. Thus, information asymmetry is naturally associated with any informing process. But the higher information asymmetry prone the higher the risk of misinforming.

Informing process and the risk of misinforming

A communication process represents an exchange of information between two parties – a sender and a receiver – through a given communication channel. The stages in a communication process are represented in Figure 1. Here we follow the Shannon's model of a communication process.

The sender sends out a message to the receiver intending to provide the receiver with information, which will assist the receiver in solving a given problem or a set of problems. The content of the message represents the sender's idea of what is useful to the receiver. The message is composed so that its meaning is intended to be understood by the sender. The composition structure and the wording of the message is influenced by the sender's judgment on the receiver's capability to understand and interpret the message content correctly. The message is encoded to make it suitable for transmission through the communication channel and submitted to the receiver.

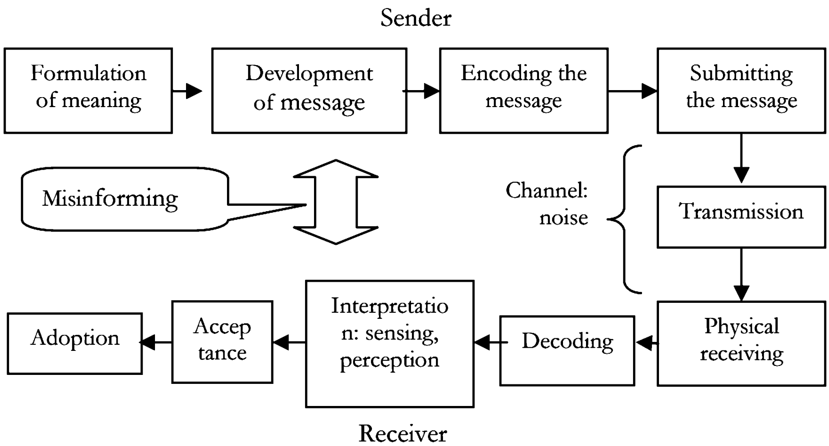

Figure 1. Stages in a communication process (adopted from Schoderbek, Schoderbek, Kefalas (1990), p.173)

From the receiver's point of view, the process also includes several stages – addressing different levels of success. It starts with the physical delivery of the message followed by its decoding, which addresses the technical aspects of the process. The decoding is the ability of the receiver to read the message, which requires an agreement between the two parties on the language used in the message and also requires that the receiver be attending to the particular channel. The understanding, i.e., the proper interpretation of the message is essential for the success of the communication process. Next stage, the acceptance of the information provided by the message, is based mostly on the trust between the two parties. The last phase - the adoption of the information - is successful if the receiver utilizes the obtained information in his/her decision making. The success of the last stage depends on the success of all of the previous stages in the communication process. Failure in any of them results in a failure in the communication.

Most of the technological tools developed to support the communication are focusing on the physical delivery and the correct decoding of the information at the receiver's end.

The stage of interpretation of the content of the message is critical to whether the message informs or misinforms the client. The interpretation is based on client's expertise, perceptions, biasness, believes, etc. The success in this stage is seriously influenced by the information asymmetry, the difference in expertise between the sender and client with respect to the content of the message.

The acceptance of the information is affected by the level of trust/credibility toward the message. The success of this phase is critically influenced by the level of sender's credibility with the client. In a face-to-face communication, the trust may be revealed by many factors beyond the content of the message, such as whether the communication takes place in a trustful environment, what is sender's personality, sender's body language, possibilities of clarifying the meaning of the message in an easy and natural dialog, etc. In indirect communication, majority of these factors are irrelevant and they have to be compensated for through the structure and the content of the message.

The last stage, the adoption of the information, depends on whether the obtained information, as it is understood, is valuable to the client and serves her/him in making decisions and solving problems. The result of informing appears on this stage – whether the obtained by the client operational knowledge agrees with the knowledge intended to be communicated by the sender.

An incorrect, not as intended, interpretation of the received message may cause significant qualitative and quantitative losses to both parties. For the client, the occurrence of misinforming may cause direct (financial) losses and for the sender, it may cause a loss of reputation. Some reduction of these losses could be achieved either by improving the quality of the sent message or by introducing tools (such as a warranty) to share the risk of misinforming between the two parties.

The primary data source for the risk of misinforming is the feedback on the client's "satisfaction" with the message sent by the sender. Studies on the success of information services originate in the area of Information Sciences (see for example Buckland 1991), where, in relatively narrow settings, the impact of a client's expertise on the success of information services was studied. The client's expertise was studied by Buckland in two aspects – the domain expertise and the expertise on how to use efficiently the information system providing the service. The level of client's expertise in the subject area affects the level of information asymmetry – a high expertise in the subject area reduces the level of information asymmetry and vice versa.

Categories of Information Processes

Our objectives are to evaluate the risk of misinforming in different realistic settings. Christozov, Chukova, Mateev (2005, 2006, and 2008) have analyzed the risk of misinforming in two cases – the risk of misinforming in offering a single product to a single buyer ("one-to-one" case) as well as the risk of misinforming in offering a single product to many buyers ("one-to-many" case). Here we extend these models by proposing a new model to cover the case "many-to-many". In our new model, we first deal with the case of offering two competing products to a group of buyers and later generalize it to the case of offering N competing products to a group of buyers.

Difficulties in Evaluating the Success in Informing

One of the main difficulties encountered in our attempts to quantify the risk of misinforming, was the description of variations in the interpretation and acceptance of the message. One and the same message may inform correctly some clients and misinform others. The misinforming could be of different degrees and consequences for the individual client within a given group, and the affect may vary between different groups of clients.

Additional difficulty in developing models for measuring the risks of misinforming can be caused by messages with multiple components. A portion of the message may inform the clients correctly regarding particular properties of the object of informing and another part of the same message may misinform them regarding other properties of the object.

For the client the risk of misinforming has subsequent impact on client actions. On the other hand, the sender is also affected by failures in informing. The sender's risk is measured by the percentage of misinformed clients, and also by the nature of the incorrect actions caused by the message.

To evaluate the risk of misinforming for a group of clients, we have to consider each and every personal reaction caused by the message, i.e., the individual risks, and to aggregate these risks over the whole group. The attitude of an individual client towards the message will allow us to divide the group of clients into sub-groups (clusters). We study the risk for these subgroups to obtain a better insight on the nature of the failures, causes and effects in the informing process.

Quantitative Measures of the Risk of Misinforming

Notations and Assumptions

In order to present the model for quantifying the risk of misinforming we need to introduce and comment on the following notations and model components.

Let us assume that there is a **group of clients of information,** say $B = \{b_j\}$, $j = 1,2,\dots,J$, that needs this information in order to solve a given set of tasks. Moreover, assume that each client b_j has his/her own **set of tasks** denoted by $A_j = \{a_{ij}\}, i = 1,2,\dots I_j$, so that each task belongs to a certain **category of tasks** $A = \{A_i^*\}, i = 1,2,\dots,I$. For example, using the Internet is a category of tasks, whereas using the Internet for downloading movies or music, or using the Internet for e-mailing or shopping, or using the Internet just for surfing are particular tasks that a given user needs to solve for. On the other hand, all of these particular tasks belong to the category of tasks "using the Internet". Every client b_j has a particular **need,** say n_{ij}, to perform task a_{ij} from category A_i^*. If a client does not need to solve a task from a given category, then the corresponding need is set to be equal to zero, i.e., $n_{ij} = 0$.

Assume that all clients from the group receive the same message D from the sender. For example, the clients may use an advertisement regarding a particular product, e.g., a personal computer, for decision whether it may solve their tasks, including the task of using the Internet. Assume that the sender's goal is to inform the clients accurately and wholly on the product. He composes a message that reflects correctly and precisely his expertise on the product. The message aims to assist the clients in their purchase decision making, as to whether this product is suitable for solving their tasks. Every client, as a party of the informing process, understands and interprets the message D according to his/her own expertise. Here, by clients' expertise we mean a set of factors, including personal background, preliminary knowledge, beliefs, culture, bias, etc. This expertise influences the decision making process and, more generally, the overall behavior of the client and individual needs for the solution of different tasks. It affects his subjective understanding of the information within the message and on how this information can be utilized in order to perform his tasks.

There are two aspects of the acceptance of the information in the message. The first one reflects the trust toward the source and the content of information. The second one relates to the extent to which the information obtained facilitates solving the clients' tasks. Here we focus on the second aspect and more specifically on the following:

1. the content that the sender aims to transmit via the message;
2. how this content, is understood, interpreted, accepted and used by the client;
3. how this content could be a source for misinforming the client.

Let's denote by $C = \{c_l\}, l = 1, 2, \ldots L$ the properties, attribute, parts, etc. of the message. Here we must note that $\{c_l\}$ are described in terms of the problems' domain. Denote by $\{q_{jil}\}, l = 1, 2, \ldots L$, the personal levels of acceptance (thresholds) for client b_j regarding her/his task a_{ij}, from category A_i^*. These are also defined in terms of the problems' domain. The level of acceptance is the threshold of the given property of the received information. Information at a level below this threshold is unusable for this client. To make these measures usable in aggregated models, we have to normalize them, $\tilde{q}_{jil} = norm(q_{jil})$ in a way to allow their interpretation as probability for acceptance $0 \le \tilde{q}_{jil} \le 1$. Such normalization can be done in many different ways, specific for every particular case. Further, we assume that the thresholds are already normalized and we will use onwards q_{jil} instead of $\tilde{q}_{jil}$. Moreover, ignoring the case when only a part of the message is useful to the client, we define the acceptance level of a message as follows:

Definition 2. The acceptance level q_{ij} of message D for solving task a_{ij} is given by $q_{ij} = \min_l(q_{jil}), l = 1, 2, \cdots, L$.

As mentioned earlier, the message provides information that allows for making decisions regarding particular tasks. Let us denote by p_i the objective ability of the provided information to solve for the category of tasks A_i^*. This is the probability that the provided information solves for any task in A_i^*. Also, let us denote by $\hat{p}_{ij}$ the subjective assessment of client b_j on whether the provided information is capable of solving his/her task a_{ij}. This is the client's subjective probability, that the received information will solve the task.

The Risk of Misinforming

Let us denote by r_{ji} the risk of client b_j in using information in message D for solving task a_{ij}. If the client does not use the information, despite of the fact that the information in the message is useful and can solve his task, then we will have $r_{ji} = 1$. In addition, if the client uses the information in the message, which does not provide a solution for his task, then again we will have $r_{ji} = 1$. In general, we have $r_{ji} = 1$ if the client makes wrong decision on whether or not to use the information in the message. With $r_{ji} = 0$ we mark the correct decision regarding the use of the information in the message.

There are six possible cases, depending on the objective, subjective assessment of the information and related acceptance level that will identify the value of r_{ji}. Namely:

1. $p_i < \hat{p}_{ij} < q_{ij}$ - the information is not suitable to solve for task a_{ij}, the client's estimation of the suitability of the information is **optimistic** and **below the degree of acceptance,** thus the decision is **negative** and **correct,** and $r_{ij}=0$;

2. $p_i < q_{ij} < \hat{p}_{ij}$ - the information is not suitable to solve for task a_{ij}, the client's estimation of the suitability of the information is **optimistic** and **above the threshold of acceptance,** thus the decision is **positive** and **wrong,** and $r_{ij}=1$;

3. $q_{ij} < p_i < \hat{p}_{ij}$ - the information is suitable to solve for task a_{ij}, the client's estimation of the suitability of the information is **optimistic** and **above the threshold of acceptance** , thus the decision is **positive** and **correct,** and $r_{ij}=0$;

4. $\hat{p}_{ij} < p_i < q_{ij}$ - the information is not suitable to solve for task a_{ij}, the client's estimation of the suitability of the information is **pessimistic** and **below the threshold of acceptance,** thus the decision is **negative** and **correct,** and $r_{ij}=0$;

5. $\hat{p}_{ij} < q_{ij} < p_i$ - the information is suitable to solve for task a_{ij}, the client's estimation of the suitability of the information is **pessimistic** and **below the threshold of acceptance**, thus the decision is **negative** and **wrong,** and $r_{ij}=1$;

6. $q_{ij} < \hat{p}_{ij} < p_i$ - the information is suitable to solve for task a_{ij}, the client's estimation of the suitability of the information is **pessimistic** and **above the threshold of acceptance**, thus the decision is **positive** and **correct,** and $r_{ij}=0$.

Definition 3. The level of error, caused by the information asymmetry, is the difference between the real capability of the message to solve for task a_{ij} and how it is assessed by the client. We call it degree of information asymmetry of task a_{ij} and denote it by $ia_{ij} = abs(p_i - \hat{p}_{ij})$.

In Table 1 we summarize all components needed for further modeling of the risk of misinforming.

Table 1. Information components of the model

Category of tasks / Client	A_1^* $\{p_1\}$	…	A_I^* $\{p_I\}$
b_1	$\{a_{11}, n_{11}, q_{11}, \hat{p}_{11}, r_{11}\}$	…	$\{a_{I1}, n_{I1}, q_{I1}, \hat{p}_{I1}, r_{I1}\}$
b_2	$\{a_{12}, n_{12}, q_{12}, \hat{p}_{12}, r_{12}\}$	…	$\{a_{I2}, n_{I2}, q_{I2}, \hat{p}_{I2}, r_{I2}\}$
…	…	…	…
b_J	$\{a_{1J}, n_{1J}, q_{1j}, \hat{p}_{1J}, r_{1J}\}$	…	$\{a_{IJ}, n_{IJ}, q_{IJ}, \hat{p}_{IJ}, r_{IJ}\}$

The questionnaires to collect feedback information regarding the degree of acceptance, needs and the subjective assessment of the capability of the information are provided in the Appendix.

"One-to-one" Informing Process: The Risk of a Client

Here we propose several models for quantifying the overall risk, regarding the tasks A_j of a particular client b_j. These models differ by the type of information available, which is of course, due to the differences in the type of the feedback data available. For example, if the needs n_{ij} are known, the proposed measure differs from the measure with unknown needs. Similarly, the measure for the risk of misinforming with known risk r_{ij} of a wrong decision or known degree of information asymmetry ia_{ij}, will differ from the measure with these information parameters unknown. We propose the following three measures, depending on which of the above information parameters (r_{ij}, n_{ij}, ia_{ij}) are known:

1. A simple model - only data regarding the risk of wrong decisions r_{ij} is available. It is not difficult to collect a feedback consisting of appropriate data to evaluate the risk of wrong decisions. For example, in commercial activities, one needs to count only the claims of the unsatisfied clients. The proposed measure of the risk of misinforming is:

$$r_j^s = \frac{1}{I}\sum_{i=1}^{I} r_{ij} \,. \tag{1}$$

2. A model with known n_{ij} and r_{ij}. We assume that if a client b_j doesn't need to solve a task from category A_i^*, then $n_{ij} = 0$, and s/he doesn't need to know or interpret the message regarding tasks from A_i^*. It is easy to see that there is a simple relationship between the level of needs and the risk of misinforming, i.e., the higher the need of a client to solve for a given task is, the higher corresponding risk of misinforming is. So, in this case, we propose the following measure for the risk of misinforming:

$$r_j^n = \frac{1}{I}\frac{1}{\sum_{i=1}^{I} n_{ij}}\sum_{i=1}^{I} n_{ij} r_{ij} \,. \tag{2}$$

3. A model with known $(r_{ij}, n_{ij}, ia_{ij})$. In this model, we collect and analyze feedback data on the degree of misunderstanding the message. The measure of the risk of misinforming in this case is more complex, but at the same time, it is more accurate. We propose the following measure:

$$r_j^a = \frac{1}{I}\frac{1}{\sum_{i=1}^{I} n_{ij}}\sum_{i=1}^{I} n_{ij} r_{ij} ia_{ij} \,. \tag{3}$$

The complexity in collecting feedback data for these models is quite different. The assessment whether a decision is correct or incorrect is trivial in the case of, so-called, clients-optimists and quite difficult for, so-called, clients-pessimists. In the first case, a client-optimist adopts and uses the received information, and eventually makes an error, which can be recorded. In the second case – a client-pessimist does not use the information and there is no data available on whether his/her potential decision would be incorrect or correct.

It seems easy to collect data regarding the needs, because a given client knows how s/he is going to use the obtained information. On the other hand, the process of informing is a learning process, which means that the needs could change over time and it is quite challenging to model this change.

Definitely, the most complex information element in the modeling is the degree of information asymmetry ia_{ij}. A questionnaire aiming to collect appropriate data to evaluate the degree of information asymmetry is given in the Appendix.

"One-to-Many" Informing Process

In generalizing the risk for the whole group of clients, we propose measures of the risk of misinforming from the point of view of the sender of information. This is the risk of how the message, composed by the sender, informs clients and whether it informs or misinforms them. This can be described as a measure of the informing quality of the message, i.e., the quality of the content and the presentation of the information, which the sender wants to communicate to her/his clients.

In the case of "one-to-many", we propose three models depending on the level of the available information, i.e., the availability of feedback data needed for the estimation of the information parameters $(r_{ij}, n_{ij}, ia_{ij})$:

1. A simple model (only r_{ij} is known). The proposed measure for the risk of misinforming is

$$R^s = \frac{1}{IJ} \sum_{j=1}^{J} \sum_{i=1}^{I} r_{ij} . \tag{4}$$

2. A model with (r_{ij}, n_{ij}) known. We propose to evaluate the risk of misinforming as follows:

$$R^n = \frac{1}{IJ} \sum_{j=1}^{J} \left(\frac{1}{\sum_{i=1}^{I} n_{ij}} \sum_{i=1}^{I} n_{ij} r_{ij} \right). \tag{5}$$

3. A model with all information parameters (r_{ij}, n_{ij}, ia_{ij}) known. The proposed measure for the risk of misinforming is given by:

$$R^a = \frac{1}{IJ}\sum_{j=1}^{J}\left(\frac{1}{\sum_{i=1}^{I} n_{ij}}\sum_{i=1}^{I} n_{ij}\, r_{ij}\, ia_{ij}\right). \tag{6}$$

An example, illustrating these models is presented in the next section.

"Two-to-one": The Case of Two Competing Messages

Next, we consider the case, when the client b_j receives two competing messages ${}^1D$ and ${}^2D$ from two competing sources of information. The client has to choose the knowledge acquired from only one of them in order to solve her/his tasks, or may choose to ignore both messages. Here we will not discuss the case of two complementary messages, meaning the client can benefit from acquiring knowledge from both messages. The client has the following options in making her/his decision:

1. choose ${}^1D$: this message is useful, the client solves her/his task a_{ij}; the decision is correct and the risk is ${}^1r_{ij} = 0$.
2. choose ${}^1D$: this message is not useful, the client doesn't solve her/his task a_{ij}; the decision is wrong and the risk is ${}^1r_{ij} = 1$.
3. choose ${}^2D$: this message is useful, the client solves her/his task a_{ij}; the decision is correct and the risk is ${}^2r_{ij} = 0$.
4. choose ${}^2D$: this message is not useful, the client doesn't solve her/his task a_{ij}; the decision is correct and the risk ${}^2r_{ij} = 1$
5. ignore both messages: ${}^1D$ is useful and the client could have solved his/her task a_{ij} if s/he has used the information from this message; the message ${}^2D$ doesn't consists of any useful

information. The decision is wrong and the risks are ${}^{1}r_{ij} = 1$ and ${}^{2}r_{ij} = 0$.

6. ignore both messages: ${}^{1}D$ is useful and the client could have solved his task a_{ij} if s/he has used the information from this message; the message ${}^{2}D$ also consists of some useful information. The decision is wrong and the risks are ${}^{1}r_{ij} = 1$ and ${}^{2}r_{ij} = 1$.
7. ignore both messages: ${}^{2}D$ is useful and client could have solved his task a_{ij} if s/he has used the information from this message; the message ${}^{1}D$ doesn't consists of any useful information. The decision is wrong and the risks are ${}^{1}r_{ij} = 0$ and ${}^{2}r_{ij} = 1$.
8. ignore both messages: both message do not consist of any useful information. The decision is correct and the risks are ${}^{1}r_{ij} = 0$ and ${}^{2}r_{ij} = 0$.

In all of the above cases, the client b_j interprets each of the two messages according to her/his need and level of acceptance for a given task and according to her/his own assessment of how useful is the received information. Regarding the task a_{ij}, the client b_j has a level of acceptance q_{ij} and a need n_{ij}, which have the same interpretation as in the case of a single message.

Furthermore, under this new setting, we have ${}^{1}p_i$ and ${}^{2}p_i$ to be the objective probabilities that each of the two messages is suitable to solve tasks from category A_i^*. Additionally, we have ${}^{1}\hat{p}_{ij}$ and ${}^{2}\hat{p}_{ij}$ to be the subjective probabilities, as assessed by the client b_j, regarding the suitability of each of the two messages to solve her/his task a_{ij}. In this model, there are 120 different cases to consider in order to identify the risks ${}^{1}r_{ij}$ and ${}^{2}r_{ij}$, compared to only 6 cases for a single message as given earlier. We assume that the client chooses to use the information from the message with higher ${}^{*}\hat{p}_{ij}$, e.g., if ${}^{1}\hat{p}_{ij}$ > ${}^{2}\hat{p}_{ij}$, s/he chooses to use ${}^{1}D$.

Similarly to the single message case, we propose three models for the evaluation of the risk of misinforming, depending on the level of the available information, i.e., the availability of feedback data needed for the estimation of the information parameters (${}^{1}r_{ij}$, ${}^{2}r_{ij}$ n_{ij}). The proposed measures for the risk of misinforming for the three models are as follows:

1. For the simple model (M1) with only (${}^{1}r_{ij}$, ${}^{2}r_{ij}$) known, we propose to measure the risk of misinforming as follows:

$$r_j^s = \frac{1}{I} \sum_{i=1}^{I} \max({}^{1}r_{ij}, {}^{2}r_{ij}) \ . \tag{7}$$

2. For model (M2) with known (${}^{1}r_{ij}$, ${}^{2}r_{ij}$ n_{ij}) and no adjustment of the risk due to the values of the objective and subjective probabilities of suitability of the messages, we propose the following measure:

$$r_j^u = \frac{1}{\sum_i n_{ij}} \sum_{i=1}^{I} n_{ij} \max({}^{1}r_{ij}, {}^{2}r_{ij}) \ . \tag{8}$$

3. For model (M3) with known (${}^{1}r_{ij}$, ${}^{2}r_{ij}$ n_{ij}), we consider a measure of the risk of misinforming, which is adjusted for the values of the objective and subjective probabilities of suitability of the messages. We propose to asses this risk as follows:

$$r_j^a = \frac{1}{\sum_i n_{ij}} \sum_{i=1}^{I} n_{ij} \max({}^{1}r_{ij}, {}^{2}r_{ij}) \left(abs\left(\max_{m=1,2}({}^{m}\hat{p}_{ij}) - {}^{\arg\max_m({}^{m}\hat{p}_{ij})}p_i\right)\right) \tag{10}$$

where $\max\limits_{m=1,2}({}^{m}\hat{p}_{ij})$ represents the better option, according to the client's subjective assessment about suitability of the message; $\arg\max_m ({}^m\hat{p}_{ij})$ is equal to 1 if ${}^1\hat{p}_{ij} > {}^2\hat{p}_{ij}$ and equal to 2 in the opposite case.

Using similar ideas, we propose measures for the risk of misinforming by any of the two messages with respect to a given category of tasks, as well as for the whole set of tasks.

1. In the simple model (M1), we propose to evaluate the risks of misinforming by message *m, m=1,2*, regarding the category A_i^* as follows:

$$ {}^mR_i^s = \frac{1}{J}\sum_{j=1}^{J} {}^m r_{ij},\ m = 1, 2. \tag{11}$$

2. In the simple model (M1), the risk of misinforming by message *m, m=1,2*, for the whole set of tasks can be evaluated as follows:

$$ {}^mR^s = \frac{1}{I\,J}\sum_{j=1}^{J}\left(\sum_{i=1}^{I} {}^m r_{ij}\right),\ m = 1, 2. \tag{12}$$

3. In model M2, we propose to evaluate the risks of misinforming by message *m, m=1,2*, regarding the category A_i^* as follows:

$$ {}^mR_i^u = \frac{1}{J}\sum_{j=1}^{J} n_{ij}\ {}^m r_{ij},\ m = 1, 2. \tag{13}$$

4. In model M2, the risk of misinforming by message *m, m=1,2*, for the whole set of tasks can be evaluated as follows:

$$ {}^mR^u = \frac{1}{J}\sum_{j=1}^{J}\left(\frac{1}{\sum_i n_{ij}}\sum_{i=1}^{I} n_{ij}\ {}^m r_{ij}\right),\ m = 1, 2. \tag{14}$$

5. In model M3, we propose to evaluate the risks of misinforming by message *m, m=1,2*, regarding the category A_i^* as follows:

$$ {}^mR_i^a = \frac{1}{\sum_j n_{ij}}\sum_{j=1}^{J} n_{ij}\ {}^m r_{ij}\ (abs(\ {}^m\hat{p}_{ij} - {}^m p_i)),\ m = 1, 2. \tag{15}$$

6. In model M3, the risk of misinforming by message *m, m=1,2*, for the whole set of tasks can be evaluated as follows:

$$^{m}R^{a} = \frac{1}{I}\sum_{i=1}^{I}\left(\frac{1}{\sum_{j} n_{ij}}\sum_{j=1}^{J} n_{ij}\,{}^{m}r_{ij}\,(abs({}^{m}\hat{p}_{ij} - {}^{m}p_{i}))\right),\ m = 1, 2. \quad (16)$$

"Many-to-Many": N competing messages

Next, we briefly comment on the model "many-to-many", where N competing messages are sent to a group $B=\{b_j\},\ j=1,2,\ldots,J$ of clients. The ideas of evaluating the risk of misinforming under the "many-to-many" model are similar to the ideas of measuring this risk in the case of "two-to-one". So, we propose measures for the risk of misinforming for "many-to-many" case by extending the measures given in (7) -(16).

1. Under M1, M2 and M3 models, the individual risks can be evaluated as follows:

$$r_j^s = \frac{1}{I}\sum_{i=1}^{I}\max_{m=1,2,\ldots N}({}^{m}r_{ij}) \quad (17)$$

$$r_j^u = \frac{1}{\sum_{i} n_{ij}}\sum_{i=1}^{I} n_{ij}\max_{m=1,2,\ldots,N}({}^{m}r_{ij}) \quad (18)$$

$$r_j^a = \frac{1}{\sum_{i} n_{ij}}\sum_{i=1}^{I} n_{ij}\max_{m=1,2,\ldots,N}({}^{m}r_{ij})\,(abs(\max_{m=1,2,\ldots,N}{}^{m}\hat{p}_{ij} - {}^{\arg\max_m({}^{m}\hat{p}_{ij})}p_{i}))\,. \quad (19)$$

2. The formulae for computing the risks of misinforming by any of the N messages, under M1, M2 and M3 with respect to category A_i^*, are listed below:

$$^{m}R_i^s = \frac{1}{J}\sum_{j=1}^{J}{}^{m}r_{ij},\quad m=1,2,\ldots,N \quad (20)$$

$$^{m}R_i^n = \frac{1}{J}\sum_{j=1}^{J}n_{ij}\ {}^{m}r_{ij},\quad m=1,2,\ldots,N \quad (21)$$

$$ {}^{m}R_{i}^{a} = \frac{1}{\sum_{j} n_{ij}} \sum_{j=1}^{J} n_{ij}\, {}^{m}r_{ij} (abs({}^{m}\hat{p}_{ij} - {}^{m}p_{i}), \quad m = 1,2,\ldots,N \qquad (22) $$

3. The formulae for evaluating the risks of misinforming by any of the N messages, under M1, M2 and M3 models for the whole set of tasks, are listed below:

$$ {}^{m}R^{s} = \frac{1}{IJ} \sum_{j=1}^{J} (\sum_{i=1}^{I} {}^{m}r_{ij}), \quad m = 1,2,\ldots N \qquad (23) $$

$$ {}^{m}R^{n} = \frac{1}{I} \sum_{i=1}^{I} (\frac{1}{\sum_{j} n_{ij}} \sum_{j=1}^{J} n_{ij}\, {}^{m}r_{ij}), \quad m = 1,2,\ldots,N \qquad (24) $$

$$ {}^{m}R^{a} = \frac{1}{I} \sum_{i=1}^{I} (\frac{1}{\sum_{j} n_{ij}} \sum_{j=1}^{J} n_{ij}\, {}^{m}r_{ij} (abs({}^{m}\hat{p}_{ij} - {}^{m}p_{i}))), \quad m = 1,2,\ldots,N \qquad (25) $$

An Example

Next, we present an application of the models for evaluating the risk of misinforming in the case of a one-to-many informing process.

The Survey

To illustrate the ideas described in this chapter, we conducted a survey and collected information needed to evaluate the risk caused by information asymmetry in the case of commercial deal, when the message is the seller's advertisement regarding a product. In our survey the product D is a personal computer (PC) with a configuration given in the Appendix. The survey was conducted in two phases. The first phase addresses the assessment of the degree of acceptance of the attributes/components of the product, related to a given category of tasks, while the second phase assesses how respondents evaluate the capability of the product to solve the various categories of tasks. The questionnaire used in the second phase consists of two parts. In the first part the respondent is offered a five-level scale to answer the questions related to her/his needs to perform a particular task and to estimate the suitability of the product in performing this task. In the second part, information regarding the preferred product warranty is collected.

The two questionnaires were offered to respondents in two stages. Initially, the respondents were asked to fill in Form 1, addressing the degree of acceptance and how often they needed to perform a particular task. After approximately one hour, the second part of the survey administered. The time gap between the first and the second part of the survey was introduced because we wanted to reduce the direct recall of information used to evaluate the degree of acceptance for the different PC components and the configuration of the particular PC given in the second part of the survey.

The survey was conducted with two independent groups of respondents, having 53 and 10 members. The first phase of the survey (Form 1) was identical for both groups. The second part was divided into two forms. The first form of the second part of the survey offered a choice between two warranty policies: one for malfunctioning (3 year replacement) and one for misunderstanding (3 month return), whereas the second form of the second part of the survey provided a third choice that was a mixture of the first two policies with shorter durations (1 year replacement and 1 month return). Each of the groups of respondents was given only one of the forms for the second part of the survey. The responses for Form 1 for both groups were collected in one dataset, while the data from the second part of the survey for the two groups were considered separately.

Preliminary Comments

From a conceptual standpoint, and if we ignore any costs associated with setting up a new PC, the best warranty strategy for any buyer is to purchase the PC with the second type of warranty. The reason is as follows. If the PC is not suitable for his/her needs, it can be turned in—as per the intent of the warrantee. If, however, the computer does prove suitable, then the purchaser can still turn it in, then promptly purchase a new one with the three years free replacement warranty.

Unfortunately, in order to assess whether a computer is suitable for solving for a particular set of tasks, quite a lot of efforts and time may have to be invested. For example, several software packages may have to be installed and tested, achieving compatibility between different software may require adjustments, the computer may need to be tuned up in order to achieve its best performance, etc. Therefore, if suitability were known in advance, it would not normally be reasonable to expend all this time and effort required to start all over again with a new computer in return for gaining only three months of extra warranty against malfunctions.

We further assume that the three months trial period offered by the second type of warranty would provide sufficient time to allow the customer to test almost all features of the product that he/she is interested in. For the third warranty option, on the other hand, we assume that one month is frequently not enough time to allow for a comprehensive examination of the suitability of the product.

The survey was conducted with two independent groups of respondents. The first one was given the choice of the first two types of warranty, while the second group had to choose from all three types of warranty. This was done in order to observe the affect of the third, mixed, warranty policy on the consumers' choice.

Results of the Survey

The two forms of the survey are given in the Appendix. In the next section we present a summary of the data and their analysis, followed by recommendations regarding the best choice of the product warranty. In interpretation we compare the results obtained in this survey with previously conducted surveys, where the degree of acceptance was set to be equal to 0.5 (see Christozov, Chukova, & Mateev, 2007).

Assumptions and default values for the model parameters

We assume, that the features of the PC, described in the survey, are evaluated by the producer using p_i's for the tasks, listed below. The values of the p_i's are given in the column on the right-hand side:

- Using word processing 1.00
- Using spreadsheets, (e.g. Excel) 1.00
- Using e-mail 0.60
- Surfing Internet 0.40
- Solving complicated problems 1.00
- Playing Games 0.20
- Watching movies 0.20
- Listening to Music 0.20

The average values of the degree of acceptance of the PC with respect to each of the considered tasks are given in Table 2. These were computed using the weights shown in Table 1 and the approach described in the previous section.

Table 2. Degree of acceptance by tasks

Word	Excel	e-mail	Internet	Complex	Game	Movies	Music
0.324	0.280	0.369	0.449	0.392	0.478	0.428	0.377

Summary of the results

In Table 3 we summarize our results s regarding the Seller's risk and in Table 4 - the results regarding the Buyer's risk.

Table 3. Seller's risk: Summary of results

	Two forms of warranty	Three forms of warranty
$R^s =$	0.450	0.431
$R^u =$	0.450	0.432
$R^a =$	0.220	0.222

Table 4. Buyer's risk: Summary of results

	Two forms of warranty			Three forms of warranty		
Category	#	$\frac{1}{n}\sum_{j=1}^{n} r_j^a$	$\frac{1}{n}\sum_{j=1}^{n} r_j^u$	#	$\frac{1}{n}\sum_{j=1}^{n} r_j^a$	$\frac{1}{n}\sum_{j=1}^{n} r_j^u$
Overall	10	0.203	0.425	53	0.213	0.438
Optimists	8	0.234	0.477	23	0.265	0.515
Pessimists	1	0.075	0.188	8	0.098	0.203
Realists	1	0.083	0.250	22	0.200	0.443
Warranty 3 months	2	0.191	0.420	4	0.242	0.496
Warranty 3 years	8	0.206	0.427	22	0.207	0.441
Warranty 1 month + 1 year				27	0.213	0.427

Interpretation

As expected, the analysis of the surveys of the two groups of respondents led to essentially equivalent results, because the surveys were conducted on two samples taken from one and the same population, namely, first-year students in non-technical majors.

The results show that the risk of misinforming is high enough to deserve attention. For this level of risk, because of domination of optimists over pessimists, the seller has to offer warranty of the third type. Also, it is clear that a very small proportion of respondents are able to recognize their inability to judge properly the qualities of the product. In the first group 2 out of 8 and in the second – 4 out of 53 have chosen the pure trial policy. The mixed policy is more attractive – 27 out of 53 have chosen this option. In our previous survey (Christozov, Chukova, & Mateev, 2007) we had the following results: in the first group only 13 out of 118 have chosen to try the product before making the final solution; in the second group 19 out of 54 have chosen the mixed warranty, whereas only one student has expressed preference for the pure trial option.

The chosen warranty option can be considered as a measure of clients' confidence regarding their purchase decision. The first option – 3 years warranty – refers to a high degree of self-confidence. The 3 months option represents low confidence and high degree of uncertainty. As expected, the survey data confirm that psychologically people have difficulties recognizing their inability to judge correctly. This is the reason for a very low number of respondents choosing the 3 months warranty option. A high percentage of respondents prefer the third option - the mixed warranty, which is a compromise between the two pure warranty policies. This result is a good illustration of the, so called, compromise effect in anchoring (for more details see Gill, 2008).

The estimated degrees of acceptance, shown in Table 2, are lower than the assumed value of $q_{ij} = q = 0.5$ in (Christozov, Chukova, & Mateev, 2007). As expected, and it was confirmed by our analysis, the lower degrees of acceptance led to the reduction of the risks. For, example, 0.213 vs. 0.296 for the overall adjusted buyers' risk and 0.438 vs. 0.492 for overall unadjusted buyers' risk in the case of three types of warranty. This effect was expected, because a lower degree of acceptance means, roughly speaking, lower quality requirements to the product, which of course, leads to less number of wrong purchase decisions and respectively lower risk of misinforming.

The risk of the seller depends on two factors. The first factor is the percentage of clients who were misled by the message, and the second is the reaction/purchase decision of the misled clients. The optimists are more likely to purchase the product, although it is not fully suitable to their needs. As a result, they will experience financial losses and dissatisfaction with the product. They will share and spread their negative judgment regarding the product and supplier among any other potential customers. It is well known, that negative information spreads much easier and faster than positive information and, thus, misled optimists could be quite harmful to the reputation of the seller. On the other hand, misled pessimists will not purchase the product, although it is fully suitable to their needs. This will not create direct financial losses and will not lead to sharing negative information regarding the seller. The survey data show that the population of respondents is dominated by optimists, which increases the impact of the risk of misinforming. In this case a natural strategy for the seller is to offer mixed warranty, which will be very attractive to clients with high degree of uncertainty regarding their decision making. The mixed warranty strategy represents the compromise option between misinforming and malfunctioning warranty. It provides clients with two-way assurance – against a wrong purchase decision and against malfunctioning of the product. On the other hand, it allows the seller to offer a compromise option, which is usually preferred by the clients (Gill, 2008).

Conclusion

The studies on the risks of misinforming are still in a very early stage, but the results obtained so far show that this risk exists and it is possible to be measured. The research findings on the risk of misinforming could provide the sellers with information that might prove especially useful in the Internet trading. In addition, designing a feasible warranty policy, as an instrument to enhance the trust between parties, requires cost-benefit analyses based upon quantified assessment of the risk of misinforming. In this study, the proposed approach to quantify the risk caused by information asymmetry is mostly practical and it needs further improvement and development.

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Appendix: Questionnaires

Dear students,

We are studying the impact of information exchange on business transactions and purchase decisions and the way this exchange affects the customer choice.

We are running the following experiment:

Firstly, we need information about your needs and applications, you are going to use, as well as the minimal configuration of the PC you need to run the application in a way suitable to your needs.

Second, assume that you are offered the opportunity to buy a personal computer (PC) at a **highly attractive price** (say, the sale price is 30% less than you would expect to pay). You have to assess level the given PC meets you needs to run applications you need as well as the warranty policy, which suits best to your purchase decision.

Form 1: Please, select the minimal configuration of the PC to meet your needs for using it for:

a) Using word processing

PC propert	Low				High
	0	1	2	3	4
CPU	0,35 GHz	1 GHz	1.6 GHz	2.4 GHz	4.8 GHz
RAM	256 MB	512 MB	1 GB	2 GB	4 GB
HDD	20 GB	40 GB	80 GB	120 GB	240 GB
VRam	16 MB	64 MB	256 MB	512 MB	1 GB
Ethernet	56 Kbs	10 Mbs	100 Mbs	1 Gbs	10 Gbs

How often you use PC for word processing	Low				High
	never	yearly	monthly	weekly	dayly
	0	1	2	3	4

b) Using spreadsheets, (e.g. Excel)

PC propert	Low				High
	0	1	2	3	4
CPU	0,35 GHz	1 GHz	1.6 GHz	2.4 GHz	4.8 GHz
RAM	256 MB	512 MB	1 GB	2 GB	4 GB
HDD	20 GB	40 GB	80 GB	120 GB	240 GB
VRam	16 MB	64 MB	256 MB	512 MB	1 GB
Ethernet	56 Kbs	10 Mbs	100 Mbs	1 Gbs	10 Gbs

How often you use PC for spreadsheets	Low				High
	never	yearly	monthly	weekly	dayly
	0	1	2	3	4

c) Using e-mail

PC propert	Low				High
	0	1	2	3	4
CPU	0,35 GHz	1 GHz	1.6 GHz	2.4 GHz	4.8 GHz
RAM	256 MB	512 MB	1 GB	2 GB	4 GB
HDD	20 GB	40 GB	80 GB	120 GB	240 GB
VRam	16 MB	64 MB	256 MB	512 MB	1 GB
Ethernet	56 Kbs	10 Mbs	100 Mbs	1 Gbs	10 Gbs

How often you use PC for word processing e-mail	Low				High
	never	yearly	monthly	weekly	dayly
	0	1	2	3	4

d) Using the Internet

PC propert	Low				High
	0	1	2	3	4
CPU	0,35 GHz	1 GHz	1.6 GHz	2.4 GHz	4.8 GHz
RAM	256 MB	512 MB	1 GB	2 GB	4 GB
HDD	20 GB	40 GB	80 GB	120 GB	240 GB
VRam	16 MB	64 MB	256 MB	512 MB	1 GB
Ethernet	56 Kbs	10 Mbs	100 Mbs	1 Gbs	10 Gbs

How often you use PC for surfing Internet	Low				High
	never	yearly	monthly	weekly	dayly
	0	1	2	3	4

e) Solving complicated computational problems

PC propert	Low				High
	0	1	2	3	4
CPU	0,35 GHz	1 GHz	1.6 GHz	2.4 GHz	4.8 GHz
RAM	256 MB	512 MB	1 GB	2 GB	4 GB
HDD	20 GB	40 GB	80 GB	120 GB	240 GB
VRam	16 MB	64 MB	256 MB	512 MB	1 GB
Ethernet	56 Kbs	10 Mbs	100 Mbs	1 Gbs	10 Gbs

How often you use PC for solving complicated computational problems	Low				High
	never	yearly	monthly	weekly	dayly
	0	1	2	3	4

f) Playing Games

PC propert	Low				High
	0	1	2	3	4
CPU	0,35 GHz	1 GHz	1.6 GHz	2.4 GHz	4.8 GHz
RAM	256 MB	512 MB	1 GB	2 GB	4 GB
HDD	20 GB	40 GB	80 GB	120 GB	240 GB
VRam	16 MB	64 MB	256 MB	512 MB	1 GB
Ethernet	56 Kbs	10 Mbs	100 Mbs	1 Gbs	10 Gbs

How often you use PC for Playing Games	Low				High
	never	yearly	monthly	weekly	dayly
	0	1	2	3	4

g) Watching movies

PC propert	Low				High
	0	1	2	3	4
CPU	0,35 GHz	1 GHz	1.6 GHz	2.4 GHz	4.8 GHz
RAM	256 MB	512 MB	1 GB	2 GB	4 GB
HDD	20 GB	40 GB	80 GB	120 GB	240 GB
VRam	16 MB	64 MB	256 MB	512 MB	1 GB
Ethernet	56 Kbs	10 Mbs	100 Mbs	1 Gbs	10 Gbs

How often you use PC for Watching movies	Low				High
	never	yearly	monthly	weekly	dayly
	0	1	2	3	4

h) Listening to Music

PC propert	Low				High
	0	1	2	3	4
CPU	0,35 GHz	1 GHz	1.6 GHz	2.4 GHz	4.8 GHz
RAM	256 MB	512 MB	1 GB	2 GB	4 GB
HDD	20 GB	40 GB	80 GB	120 GB	240 GB
VRam	16 MB	64 MB	256 MB	512 MB	1 GB
Ethernet	56 Kbs	10 Mbs	100 Mbs	1 Gbs	10 Gbs

How often you use PC for Listening to Music	Low				High
	never	yearly	monthly	weekly	dayly
	0	1	2	3	4

Form 2 (group with three warranty options): Please consider the following PC:

AMD 64 Professional Pack: AMD Athlon 64 4800+ Quad Core

Hardware

- 107S 17" Flat Screen Beige or Black
- PowerColour X300SE 64MB PCI Express Video Card
- 2 GB DDR 400 RAM
- Seagate 160GB Serial ATA Hard Drive
- Samsung Internal IDE 52/24/52 CDRW
- 3.5" Floppy Drive
- 56 kbps V92 PCI Fax Modem
- Integrated 10/100 Network Card
- Microsoft Multimedia Keyboard
- Microsoft Optical Wheel Mouse
- Microsoft Windows XP Home Edition OEM

Bundled Software

- Microsoft Windows XP Home

- Open Office ver 2 consisting of:
- Calc - MS Excel-compatible spreadsheet
- Writer - MS Word-compatible word processor
- Impress - MS Powerpoint-compatible presentations
- Draw - Drawing program
- AVG Antivirus

We need your input on the following:

1. **Please fill in the table** below by ticking the box that best represents your needs in order to perform the stated task (listed in the first column) and your opinion on the extent to which the offered computer is capable of satisfying them.

Task	Degree of your needs					The PC degree of capability				
	Low				High	Low				High
	0	1	2	3	4	0	1	2	3	4
Using word processing										
Using spreadsheets, (e.g. Excel)										
Using e-mail										
Using the Internet										
Solving complicated problems										
Playing Games										
Watching movies										
Listening to Music										

Which warranty option would you prefer for your purchase? Please, choose **ONE** of the options listed below, by ticking the box on the right:

The PC is replaced or repaired free of charge to the customer if it fails within the first **THREE years** after the sale date.	☐
The customer will get full refund if he/she is not fully satisfied with the PC within the **first THREE months** after the sale date.	☐
The customer will get full refund if he/she is not fully satisfied with the PC within **the FIRST month** after purchasing AND the PC is replaced or repaired free of charge to the customer if it fails within **ONE year** after the sale date.	☐

Form 2 (group with two warranty options): Please consider the following PC:

AMD 64 Professional Pack: AMD Athlon 64 4800+ Quad Core

Hardware

- 107S 17" Flat Screen Beige or Black
- PowerColour X300SE 64MB PCI Express Video Card
- 2 GB DDR 400 RAM
- Seagate 160GB Serial ATA Hard Drive
- Samsung Internal IDE 52/24/52 CDRW
- 3.5" Floppy Drive
- 56 kbps V92 PCI Fax Modem
- Integrated 10/100 Network Card
- Microsoft Multimedia Keyboard
- Microsoft Optical Wheel Mouse
- Microsoft Windows XP Home Edition OEM

Bundled Software

- Microsoft Windows XP Home
- Open Office ver 2 consisting of:
- Calc - MS Excel-compatible spreadsheet
- Writer - MS Word-compatible word processor
- Impress - MS Powerpoint-compatible presentations
- Draw - Drawing program
- AVG Antivirus

We need your input on the following:

2. **Please fill in the table** below by ticking the box that best represents your needs in order to perform the stated task (listed in the first column) and your opinion on the extent to which the offered computer is capable of satisfying them.

Task	Degree of your needs					The PC degree of capability				
	Low			High		Low				High
	0	1	2	3	4	0	1	2	3	4
Using word processing										
Using spreadsheets, (e.g. Excel)										
Using e-mail										
Using the Internet										
Solving complicated problems										
Playing Games										
Watching movies										
Listening to Music										

Which warranty option would you prefer for your purchase? Please, choose **ONE** of the options listed below, by ticking the box on the right:

The PC is replaced or repaired free of charge to the customer if it fails within the first **THREE years** after the sale date.	☐
The customer will get full refund if he/she is not fully satisfied with the PC within the **first THREE months** after the sale date.	☐

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Chapter 12

The Rugged Fitness Landscape and Informing Science Research

T. Grandon Gill

Introduction

At the core of informing science is the need to better understand the interplay between the components of an informing system: the sender, the client, the delivery system, and the task to be performed. Implicit in this understanding is a notion of *fit.* For example, if the client is in a rural area of a developing country served only by telephone lines that are subject to intermittent failure and the sender wishes to convey large amounts of information in video format, then the use of an Internet-based delivery system is unlikely to be a good fit with the informing need. Similarly, if the task to be performed is highly interactive and requires ongoing exchange of information with the client, then a system providing two-way communication is likely to be a better fit than a system that only allows one-way broadcast of information. If we attach a numerical or ordinal value to the level of fit, we can refer to that value as a *fitness* value. If we were to consider a whole variety of different possible informing systems for achieving the same purpose and were to attach a fitness value to each one, we have the beginnings of a *fitness landscape.* To develop a complete fitness landscape, we would need to develop a function that can take any combination of informing system characteristics and map them to an associated fitness value. The optimal possible system would then be that collection of characteristics that maps to the highest fitness value. It is probably not an exaggeration to assert that most research in informing science is motivated by the desire to contribute, directly or indirectly, to our understanding of the fitness landscape associated with informing.

In our goal to better understand the fitness landscape for informing systems, it is useful to learn from other disciplines—many of which have their own versions of the fitness function. In economics, for example, consumers strive to maximize utility—a function that maps the bundle of goods and services they consume to a satisfaction-related value. Producers are frequently modeled as attempting to maximize shareholder value, another measure of fitness. In computer science, the concept of fitness is routinely employed in evaluator functions. A chess program, for example, will normally choose its move based upon assessing the fitness of the alternative board positions that may result. Genetic algorithms use reproductive and mutation rules originally observed in natural systems in an effort to seek solutions of maximal fitness. The concept of fitness is particularly prevalent in biological sciences. Evolutionary biologists, for example, view fitness as a survivability function representing the likelihood of reproductive success that may be applied at many different levels—from the gene to an entire species. If fitness is insufficient, the gene or species ultimately disappears if it fails to evolve or adapt.

The present chapter is intended to as a non-mathematical introduction to the nature of fitness landscapes, with particular attention being paid to the potential implications for research in informing science. It begins by presenting a continuum used to characterize fitness landscapes that was first introduced in evolutionary biology (e.g., Kauffman, 1993). In this model, landscapes range from decomposable to rugged to chaotic. The chapter then demonstrates how the continuum strongly resembles another continuum: that of science and art. The remainder of the chapter focuses specifically on rugged landscapes, emphasizing two main themes. First, it argues that the conditions that are likely to lead to a rugged fitness landscape are nearly always going to be present in informing systems. Second, it considers the many ways in which rigorous research conducted on a rugged fitness landscape can—or, more precisely, should—differ from research that assumes underlying decomposability.

Fitness Functions and Landscapes

A fitness function serves to map a set of attributes into a single value that is indicative of the desirability of the particular combination. Conceptually, this function can be represented as:

$$F = f(x_1, x_2, \ldots, x_N)$$

Where F is the fitness associated with a particular combination of specific values for the attributes x_1 through x_N. The term fitness landscape is used to refer to the behavior of the fitness function across the set of all possible values of its attributes. Conceptually, this corresponds to the "shape" of the function.

The desirability aspect of a fitness function typically manifests itself in one or both of two ways:

1. *It may signify the survivability of a particular attribute combination.* In biology and in genetic algorithms, for example, entities with higher fitness values are more likely to survive from one generation to the next than those with much lower values.
2. *It may serve to guide choice.* In economics, for example, an underlying axiom of individual behavior involves choosing that basket of goods and services which maximizes utility, which is to say the fitness of the combination.

The differences between the two forms of fitness may be less significant than might first appear. Evolutionary economists, for example, argue that our utility preferences are, in fact, simply the evolved manifestation of characteristics that have—at least in the past—contributed to individual survival (Gandolfi, Gandolfi, & Barash, 2002). Similarly, the survivability of a particular product is likely to depend heavily on the utility it inspires in its prospective customers.

The simplicity of our conceptual representation of a fitness function should not be taken as suggesting that such functions are simple. To the contrary, beyond the matter of how the function behaves—which, as we shall find, can be quite complex—finding a suitable representation for the attributes being considered is, by no means, a trivial matter. Suppose, for example, we wanted to construct the fitness function for a particular recipe that characterized—based upon the arguments supplied—how tasty the resulting dish would be. Among the elements we would need to represent are included:

- The nature and quantity of the ingredients
- The timing of insertion of the ingredients
- The specific actions that we would need to perform upon those ingredients
- The timing of those actions, and
- The tools and equipment required.

Furthermore, among those attributes which are quantitative in character, such as ingredient amounts in our example, the relationship between fitness (taste) and quantity is unlikely to be linear. For example, as shown in Figure 1, it is likely that some optimal amount of an ingredient, such as a sugar, will be present. Either more or less than that amount will lead to lower fitness—meaning the resulting dish will be less tasty.

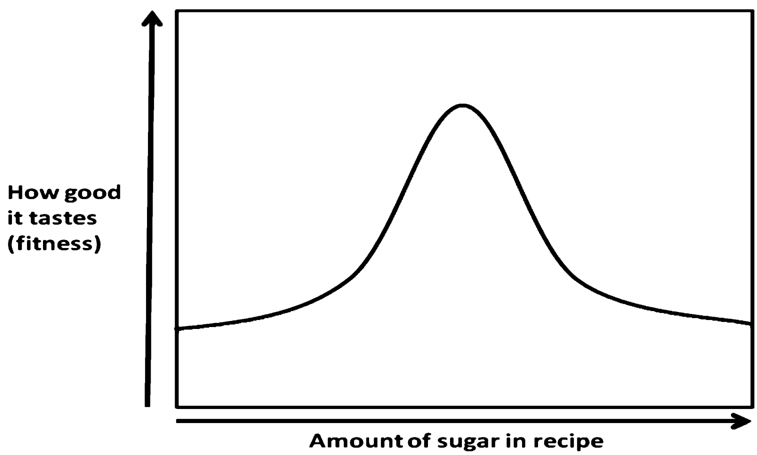

Figure1: Mapping between taste and amount of sugar in a hypothetical recipe

The shape of the curve presented in Figure 1 is our first example of a fitness peak. If we are trying to maximize the taste value of a 1 kilogram cake (as assessed by some specified individual) we would anticipate that every ingredient (i.e., argument to the fitness function) would exert a qualitatively similar influence on fitness, as would other continuous measures such as oven temperature. If we had only two ingredients, the resulting fitness space would look like a mountain with the peak representing the optimal combination of the two ingredients. With more ingredients, the precise shape of the function is harder to visualize but, conceptually, can still be thought of as a peak.

The recipe example is also useful because it can be used to illustrate the notion of migration to peak fitness. Presuming the recipe has been taken from a time-tested cookbook, there is an excellent chance that many different versions of the recipe—featuring different proportions of the relevant ingredients and different treatments (e.g., baking times, temperatures)—were tested and the one chosen for publication reflected that combination maximizing fitness as assessed by the recipe testers. In the broader fitness landscape of all recipes, we would then say that our particular recipe occupies a local fitness peak. This means that while other recipes may have higher fitness (our testers may actually prefer chocolate cake to yellow cake), there is no incremental change to our yellow cake recipe that makes it more fit—all such changes reduce fitness. In many disciplines, such as economics, it is axiomatic that observed decisions collected from a fitness landscape represent the results of individual attempts to maximize fitness.

Landscape Shapes

The preceding recipe example demonstrates how a fitness landscape can have a peak. That is, however, only one type of peak that may be present in a fitness landscape. To better understand landscape shape, we need to examine the concepts of decomposability and ruggedness.

The decomposability of a fitness function defines the degree to which the impact of each individual attribute upon fitness is independent of the values of the other attributes. For example, suppose a particular fitness function can be represented as:

$$F = f(x_1,x_2,\ldots,x_N)$$

That function is fully decomposable if we can also represent it as:

$$F = y_1(x_1) + y_2(x_2) +\ldots+ y_N(x_N)$$

where y_1 through y_N are functions that transform the raw x values into their marginal contribution to fitness. For example, the y_{SUGAR} in the recipe example would take into account the peaked shape of sugar's impact on taste. For simplicity's sake, we can abbreviate the functions in a decomposable landscape as follows:

$$F = y_1 + y_2 +\ldots+ y_N$$

At the other extreme, a fitness function may be completely non-decomposable—leading to a *maximally rugged fitness landscape,* later referred to as a *chaotic landscape*. What this means is that the contribution of a particular attribute to fitness cannot be determined without knowing the value of the other attributes. To use a somewhat contrived example as an illustration, suppose you were a participant in a game show where you could win: 1) a week-long vacation at a ski resort OR a week-long vacation at an ocean resort (each valued at $2000), 2) a plane ticket to the ski resort OR a plane ticket to the ocean resort (each valued at $750), 3) a week long rental of ski gear OR a week long rental of scuba gear (each valued at $400), and 4) $800 in cash. In addition, for the sake of the example, assume that you are not able to trade or sell any of your prizes AND that you were unwilling to spend any of your existing resources during the vacation. In this case, you might have a utility function such as the one presented below:

Table 1: Non-Decomposable Utility Matrix

0 = Ski Resort 1 = Beach Resort	0 = Ticket to Mountains 1 = Ticket to Ocean	0 = Ski Gear 1 = Scuba Gear	Utility
0	0	0	1.0
0	0	1	0.75
0	1	0	0.5
0	1	1	0.25
1	0	0	0.25
1	0	1	0.48
1	1	0	0.73
1	1	1	0.95

In the top and bottom cases, perfect fit is achieved and utility is maximized (two peaks), with skiing being slightly preferred. In the case where only the gear is mismatched, positive utility is achieved that is reduced by the need to spend prize money to cover the gear costs. Where resort and gear are consistent, utility is still lower since nearly all your cash would be drained by the plane fare. In the remaining two cases, where the plane ticket matches the gear but does not match resort, the prize has a value equal only to the utility resulting from the amount of cash provided since you cannot afford the resort and are therefore unable to take advantage of any of the other prizes.

Kauffman's NK Model

Kauffman's (1993) NK landscape model provides a tool for characterizing the decomposability of fitness functions such as the example presented in Table 1. Originally developed to simulate the fitness of a chromosome, the N refers to the number of genes. The K, in turn, refers to the average number of other genes whose values must be ascertained before the contribution of a particular gene to fitness can be determined. It is, therefore, a measure of interdependence between arguments. The model has two extreme points:

- **N, 0**: At this point each gene contributes to fitness independently, leading to a *fully decomposable landscape.*
- **N, N-1**: At this point the impact of a given characteristic on fitness can only be determined by considering the value of every other characteristic. As a consequence of this complete interdependency, no meaningful estimate of fitness can be made without knowing the values of all N characteristics. We'll refer to this landscape as the *chaotic landscape.*

For a decomposable (N,0) fitness landscape, there will be a single fitness peak at which point the fitness values y_1 through y_N are individually maximized. Somewhat less immediately obvious, and at the other extreme, the chaotic (N, N-1) fitness landscape can, for all intents and purposes, be modeled as a set of random numbers (Kauffman, 1993), thereby ensuring that no separable relationships between a subset of elements and fitness are likely to occur.

To fully understand the nature of the chaotic landscape, we need to realize that in order to model it *accurately* with a tool such as multiple linear regression, we would need to create a separate interaction term for every possible combination of values—meaning that there would be $2^N - 1$ coefficients plus a constant. Assuming that we had enough observations so that there was at least one in every cell and assuming minimal error, we would then be able to estimate the fitness of each cell in the landscape. If, on the other hand, we attempt to fit that N,N-1 landscape with a decomposable model (i.e., with N coefficients), the only significances that *should be* observed would be coincidental.

If a chaotic fitness landscape is modeled as a field of random numbers, it follows mathematically that such landscapes will necessarily have a large number of local fitness peaks (i.e., combinations of $x_1,x_2,\ldots,x_N$ where changing any single value will lead to a decline in fitness). Specifically, when only moves to adjacent fitness sites values are considered, the estimated number of these peaks will be given by a formula (Kauffman, 1993, p. 47):

$2^N / (N+1)$

An example of this is presented in Figure 2, illustrating an NK space of dimension 6,5. The peak locations are indicated by the values in parentheses. To interpret this figure, the combination of the left column and top row represent the 6 argument values to the fitness function, while the values in the central cells provide the related (randomly generated) fitness values. For example:

$F(0,1,1,1,0,1) \equiv .771$, which happens to be a peak

To determine that a value is a peak, the six adjacent cells need to be examined. In the case of 011101 (commas omitted), these would be 111101 (0.114), 001101 (0.198), 010101 (0.181), 011001 (0.658), 011111 (0.059), and 011100 (0.090). The estimated number of peaks for a 6,5 NK landscape would be roughly 9 ($2^6/(6+1) = 64/7$), with the actual number found in the example being 10. (A more detailed look at constructing a rugged fitness landscape using a spreadsheet is presented in Gill & Sincich, 2008). As the value of K declines, the number of peaks in the landscape will also decline until, when K=0, a single peak remains.

	0,0,0	0,0,1	0,1,0	0,1,1	1,0,0	1,0,1	1,1,0	1,1,1
0,0,0	0.811	0.058	0.265	0.433	(.865)	0.462	0.352	0.258
0,0,1	0.756	0.658	0.720	0.753	0.154	0.198	0.170	0.362
0,1,0	0.143	0.518	0.488	0.503	(.905)	0.181	0.868	(.937)
0,1,1	0.729	0.057	(.795)	0.230	0.090	(.771)	0.084	0.059
1,0,0	0.239	0.841	0.820	0.656	0.413	0.559	(.96)	0.581
1,0,1	0.178	(.852)	0.770	0.842	0.468	0.843	0.672	0.162
1,1,0	(.807)	0.263	0.776	0.120	0.252	(.728)	0.228	0.935
1,1,1	0.495	0.115	0.446	(.926)	0.219	0.114	(.679)	0.328

Figure 2: Local fitness peaks (in parentheses) on a randomly generated NK fitness landscape of dimension 6,5. Row headers indicate the first three attribute values, column headers the last three.

Increasing Fitness

An obvious motivation for conducting research that leads to a better understanding of a given fitness landscape is to identify actions that will lead to improved fitness. Landscape shape in general—and the number of local fitness peaks in particular—exert a major influence on what we can reasonably expect to achieve from such research.

Where the fitness landscape is decomposable, the process by which fitness can be increased is relatively straightforward. Because each characteristic that contributes to fitness does so independently, we can examine each characteristic independently *and*, once we understand how that characteristic contributes to fitness, we will not need to revisit it.

To provide a concrete example, suppose a national magazine publishes a list that ranks universities. Further suppose, as is commonly the case, that such a list is constructed by taking a set of attributes (x_1 through x_N), each weighted by some undisclosed factor (a_i) and then summed, to compute a score (S) for every university, e.g.,

$$S = a_1x_1 + a_2x_2 + \ldots + a_Nx_N$$

This formula would obviously meet the criteria of a fully decomposable fitness function since the contribution of a particular attribute—e.g., whether or not the institution has a football team—would be the same amount no matter what other attributes the institution has or doesn't have. To determine the impact of the football team attribute, an institution would simply need to add a football team and see what happened to its ranking. If fielding a team seemed too expensive for the sake of information gathering, the researcher might attempt to find two institutions whose characteristics differed only in the presence/absence of a football team and observe how their rankings differed on the list. If such a comparison were not available, the researcher might gather the characteristics of a sample of universities and then use a statistical tool—such as multiple linear regression analysis—to estimate the coefficient weights for each characteristic, including the presence/absence of a football team. Any of these techniques would work because each attribute's impact is entirely independent of the impact of any other attribute.

Even where a fitness function is fully decomposable, the process of achieving optimal fitness may prove far from trivial. There may, for example, be constraints—such as the availability of budgetary resources—that prevent an entity from optimizing all attributes simultaneously. The fitness benefits of a football team may need to be weighed against the construction of a new science building, since sufficient funds are not available for both. Where decomposability is present, however, algorithmic approaches to optimizing fitness—such as linear or integer programming—are often available that dramatically reduce the amount of searching that must be done in order to optimize fitness given a particular set of constraints. Thus, it is acquiring an understanding of the underlying nature of the global fitness function that is the principal challenge in a decomposable landscape; once the function is understood, the process of moving towards high, indeed optimal, fitness can be relatively mechanical.

The situation is entirely different for a rugged landscape. As the number of characteristics relevant to fitness grows, algorithmic or exhaustive search becomes impossible. There are simply too many possible combinations. To justify this assertion, let us imagine that the fitness of a university was, in fact, governed by a chaotic fitness function. As it happens, in the late 1980s the author developed college search software that attempted to capture the main attributes of each institution. Roughly 500 bits were used to encode relevant characteristics, such as the presence or absence of several hundred undergraduate majors, the presence or absence of different sports, average entering test scores, geographic location, campus setting, and size. If a chaotic fitness function existed, the landscape would be 500,499 in NK model terms, meaning that 2^{500} different combinations could be generated, each with its own fitness, and roughly 2^{491} ($\sim10^{150}$) local fitness peaks could be anticipated based on the formula $2^N/N+1$. Since both these numbers are unimaginably larger than the number of atoms in the universe, any attempt to search the fitness landscape by brute force would be certain to fail. But, in a chaotic landscape, brute force is the only technique guaranteeing that a fitness maximum will be achieved. Thus, the best one can hope to achieve is a deep understanding of how fitness behaves near a particular local peak or a small number of alternative peaks.

Even when the value of K is much closer to 0 than it is to N, we quickly reach a point where achieving fitness increases through manipulating attributes becomes much more difficult than it is for the fully decomposable case. Continuing with our preceding example, suppose university rankings were computed in an entirely different manner: by estimating the number of students for whom each institution represented the "best choice", subsequently referred to as best choice fitness. Although no existing college ranking system—to the best of the author's knowledge—is actually constructed in this manner, we may reasonably speculate as to how it might behave and as to how it would differ from more traditional rankings. To begin with, the fitness score for a university would necessarily depend upon its ability to best meet the needs of particular subsets of the population of potential students. Many attributes that would independently contribute to fitness in traditional ranking systems, such as scores on standardized college entry tests, would impact the "best choice" metric differently. For example, elite universities often boast S.A.T. scores in the top 1% of all students; under the "best choice" system such a criterion would eliminate 99% of the population of potential students from consideration, potentially reducing fitness. Similarly, some attributes that would not impact rankings under normal systems, such as whether an institution was liberal or conservative in its political leanings, might exert a great impact on determining whether or not it was a good fit for a particular student—for one group of students a left-wing outlook might increase fit, while for others it would reduce it. Another aspect of the best choice ranking system would be a strong motivation for institutions to migrate towards customized missions that target particular clusters of students. In the traditional ranking system, universities would tend to maximize fitness in the same way, since fitness for each is determined using the same set of attributes. Under best choice fitness, institutions would benefit from continuously searching for large subsets of the potential student universe whose needs were not being well met by other universities that also happened to be a reasonably close match to the university's existing characteristics.

It should be evident that the principal challenge presented by best choice fitness stems from the lack of decomposability in the relationship between institutional attributes and student characteristics. For example, universities targeting students who want to leave home for college might do best by investing money in dormitories and emphasizing classes that meet during the day so as to match the desires of full-time students; universities targeting the local population, particularly the local working population, might emphasize night classes and part time programs. In regions serving the economically disadvantaged, low cost community colleges might exhibit far greater fitness than more traditional, higher-priced schools that focus on a national pool of affluent students by providing luxurious surroundings at a high price tag. On the other hand, because we assume the landscape is not chaotic, and that K is probably much closer to 0 than to N, we may also reasonably expect than some attributes may contribute to fitness relatively independently of other attributes. The ephemeral "quality of teaching" might be an example of such an attribute—although a counter-argument could also be made that teaching quality will have less of an impact on fitness in institutions whose target clientele is high achieving self-motivated students than for institutions targeting first-in-family college students.

Increasing fitness in a rugged landscape is vastly more difficult than it is for decomposable landscapes. This difficulty stems from two sources. First, it is much harder to assess if fitness changes that are observed in one entity are going to generalize to another. For example, the observed positive fitness impact of adding a football program to small full time college may be quite different than it would be for a large urban university whose student base consists mainly of part time commuters. Second, although experimenting with individual characteristics one at a time can lead to incremental fitness increases, eventually the entity will reach a point at which every change leads to declines in fitness. At that point, the entity has reached a *local fitness peak*. The problem is that such peaks will not necessarily exist at very high fitness levels. The analogy here is that of climbing a mountain by ensuring that every step you take is in a direction that leads to an increase in altitude. Eventually, you will reach a peak. It may, however, be the top of a foothill rather than a mountain summit. Returning to our university illustration, some missions—no matter how perfectly they are carried out—may never be the best fit for a significant number of students. Thus, if acceptable fitness levels are to be achieved, an entity may, from time to time, need to consciously jump from one place in the landscape to another in the quest for alternative (higher) fitness peaks.

A variety of mechanisms for changing attributes in the quest to increase fitness have been observed in the study of genetics. Many of these, including sexual reproduction, cross-over, inversion and mutation, have been adapted to other search situations, such as genetic algorithms (Holland, 1992). The challenge of designing such search is in balancing the need to increase fitness through incremental changes (e.g., mutation) with the need to continue a wider exploration of the landscape so as to avoid settling for an unacceptably low peak (e.g., sexual reproduction, cross-over, and inversion). In addition, analogous to the peaks in a mountain range, the process of moving incrementally from one local peak to another often requires transiting through values of lower fitness. In some cases, these valleys in fitness may be so low that the entity fails to survive the trip.

Dynamic Fitness Landscapes

Up to this point, the model presented assumes that attempts to increase fitness are taking place on a fixed landscape. This would, of course, be a severe limitation for any model intended to be realistic. Transformations to the fitness landscape are presumed to come from two sources: adaptation of existing entities on the landscape and interaction with coupled, coevolving landscapes. We will now consider each of these.

Although we have treated fitness as a function of a set of situational characteristics, in many cases it will also depend on the characteristics of other entities occupying the same fitness landscape. This is likely to be particularly true for rugged landscapes. For example, the number of students for whom a university is the "best choice" will depend not only upon the characteristics of the university but also upon what other universities are attempting to attract the same target group of students. In such a fitness space, we would expect continual adaptation and refinement by the associated entities. In some cases, an equilibrium state might be achieved where all entities reach local peaks. In others, adaptive cycling might continue indefinitely.

A considerable number of examples, drawn from many domains, suggest that the adaptation process generally follows a characteristic pattern: extended periods of relative stability interrupted by short bursts of rapid transformation. Per Bak, a colleague of Kauffman's, studied the phenomenon extensively, referring to it as punctuated equilibrium (Bak, 1996). The magnitude and frequency of the sharp transitions are distributed roughly according to a power law (the logarithm of magnitude plotted against the logarithm of frequency is a straight line), whereby smaller disruptions occur more frequently than larger disruptions. Such a law appears to govern many unrelated phenomena, such as avalanches on a sand pile, earthquakes and biological extinction events. A number of researchers in business have observed a similar pattern of sharp changes in business environments as well (e.g., Gersick, 1991; Gill, 1995; Handy, 1990). As a general rule, the frequency of transitions tends to grow with the ruggedness of the fitness landscape. Thus, we would expect that the ability of entities to adapt would contribute more significantly to survival on such landscapes.

Kauffman's (1993) NK landscape model takes another view of dynamic fitness landscapes, attributing changes principally to coevolution. The coevolution model assumes two or more separate fitness landscapes are coupled together as a result of interdependencies. For example, the fitness landscape of a particular plant species might depend upon the population of a particular animal that eats its fruit and later evacuates its seeds in distant locations. The fitness of that animal species might, in turn, depend upon the availability of that plant species. Thus, they might contribute to each other in a synergistic way. It might also be the case, however, that the same animal will chew on the plant's leaves—thereby reducing its fitness—if insufficient fruit is available. Thus, a delicate dance between the fitness of one landscape and another could ensue.

In our university example, demographic changes that result from generational decisions regarding whether or not to have children can dramatically impact the size of the student pool. Economic changes, both relating to geographic regions and impacting parental willingness to invest in the education of such children, would similarly impact the best choice fitness metric. Thus, a university that pursues best choice fitness would face a continuously changing landscape. In order to survive, it once again follows that adaptability would be an important characteristic for such an institution to cultivate.

Decomposable landscapes tend to be much more stable than rugged landscapes. To take a simple example, suppose a farmer is trying to select a seed variety for the next year's planting. A number of important characteristics will impact the fitness of a particular seed choice: expected yield, disease resistance, the projected quality of the crop (e.g., protein content), the expected cost of inputs (e.g., fertilizer, pesticides), and so forth. These factors could each be accounted for independently in a profit equation (i.e., fitness) and the "best" seed could then be selected. Assuming farmers in a particular area were limited to a single crop, it would make no difference whether or not all your neighbors also planted the same variety of seed. Although the abundance of yield might impact price adversely—therefore lowering the fitness of the seed—you would still be better off planting the best seed as opposed to a lesser seed. Similarly, if overall demand for the crop dropped (co-evolution), you would still be better off with the best seed than with some other seed associated with the same crop. Although it is true that certain co-evolutionary effects could change fitness to another seed—for example, a sharp spike in input costs could make a seed with lower input requirements and lesser yield the new optimal choice—the same factors that impact one farmer would impact all, leading to a mass migration to the new seed during the subsequent planting season. The orderly nature of the decomposable fitness landscape comes with a hidden cost, however. The fact that all entities are drawn to a single peak means that should transformations occur that dramatically reduce the fitness of that peak, the survival rate of entities may be very low. In our agricultural example, depending solely on a single seed variety or crop increases vulnerability to an unexpected loss of fitness specific to the choice. An example of the price to be paid for such dependence can be found in the Irish Potato Famine of the mid-1800s, where extreme dependence on a single crop combined with the emergence of a disease that attacked the same crop led to a humanitarian disaster of extraordinary magnitude.

The example just presented illustrates a central theme in Kauffman's (1993) evolutionary theory. Specifically, where a fitness landscape is likely to be subject to transformations, a fundamental tradeoff between efficiency and adaptability is likely to emerge. As we have already seen, in NK landscapes where K → N, the number of peaks increases; it is also necessarily true that the average fitness of those peaks declines. As a result, entities migrating to peaks in highly chaotic landscapes are unlikely to be particularly fit, adversely affecting the survivability of such landscapes. On the other hand, where significant internal or external forces transform the landscape, the widespread distribution of peaks means that many entities will already be close to post-transformation peaks. Thus, the landscape is very adaptable.

In the other direction, as decomposability increases (i.e., K→ 0), so does the average fitness of entities on peaks—the difference between peak and average fitness tending to be greatest in the single peak case of K=0. Thus, the ability of entities to achieve peak efficiency tends to be maximized in decomposable landscapes. If a major external force transforms the landscape, however, entities that were formerly at the peak may find themselves a great distance from the post-transformation peak or peaks. That means that there is a strong likelihood that local migration will lead to a suboptimal peak or will require a long migration though low fitness values in order to reach a suitable peak. In nature, and in business, such long migrations to a totally new region of the fitness landscape are likely to be accompanied by considerable risk of extinction. Thus, entities existing on landscapes where $K \rightarrow 0$ will tend to exhibit low adaptability.

What Kauffman (1993) proposes is that for a gene or species to evolve successfully it must achieve a balance between efficiency and adaptability—a boundary he refers to as the edge of order and chaos. For a particular entity, this balance will be impacted by the rate of change in coupled environments that are coevolving. Where coevolution is slow, the boundary moves towards decomposability; where coevolution is rapid, a more rugged landscape is favored.

The Fitness Continuum from Science to Art

The concept of a fitness landscape can also be useful in considering how science and art can be distinguished. Both science and art can benefit from research—the nature and objectives of that research differ significantly, however. This becomes important when we later consider how ruggedness might impact the manner in which we design research within informing science.

As we have already emphasized, fitness is often interpreted in terms of the likelihood that an entity will survive from generation to generation. There is no particular reason that the relevant entity could not be a theory or equation. Viewed in this context, nearly all research in the "hard sciences" can be cast in fitness terms, where an important contributor to the fitness of a particular theory is likely to be the degree to which its predictions match observed outcomes. A simplistic expression of such fitness might be:

$$F = -|O(x_1,x_2,\ldots,x_N) - P(x_1,x_2,\ldots,x_N)|$$

where F is the fitness of our theory, O is an observed outcome for attributes $x_1,x_2,\ldots,x_N$ and P is the theory-predicted outcome for attributes $x_1,x_2,\ldots,x_N$. Theories that are highly fit will tend to produce differences that are consistently 0 or very small. Additional contributors to theory fitness would include:

- *Compactness:* for a given level of predictive accuracy, smaller numbers of variables (N, in the above notation) would be more fit than larger numbers. This is, essentially, a restatement of the principle known as Occam's Razor.

- *Robustness:* The greater the domain of predictive accuracy (i.e., the range of x_1, through x_N over which error is low), the more fit the theory.
- *Reliability:* The degree to which a given set of values for $x_1, x_2, \ldots, x_N$ produces consistent predictions. Where consistency is not present the implication would be that $x_1, x_2, \ldots, x_N$ may never be sufficient to explain observed behaviors. Challenges to reliability often stem from inability to estimate or measure tacit attributes accurately. They may also be the result of embedded characteristics within the theory such as irreducible uncertainty (e.g., in quantum mechanics electron positions are described by a probability cloud) or sensitive dependence on initial conditions (e.g., chaos theory).

Although it would be a serious mistake to underestimate the impact of social forces in the adoption of a particular theory (e.g., Kuhn, 1970), once established a highly fit theory can be expected to survive for a very long time.

The source of a particular theory in the sciences may be a mathematical derivation or a synthesis of empirical observations. Sometimes, in fields such as economics, it is a combination of the two—with the value of unknown parameters appearing in mathematical formulations being estimated through statistical techniques (e.g., multiple regression, structural equation modeling, and factor analysis) applied to observations. The suitability of such techniques for analyzing rugged fitness landscapes will be summarized later in the chapter and investigated in greater detail elsewhere (Gill & Sincich, 2008).

The concept of a fitness landscape is as applicable to works of art as it is to scientific equations. Some works of art survive for centuries, even millennia. Others are quickly discarded or forgotten. Interestingly, it is relatively easy to describe the functional form and arguments for many types of original art works. For example:

- *Marble Sculpture:* The arguments to the fitness function would be an array of three dimensional pixels, of a resolution just below the threshold of the human eye's ability to detect granularity, each of which is a bit for which 0 is no rock, 1 is rock. For such a function, N might by 10,000 x 10,000 x 10, 000, or 10^{12}.

- *Oil Painting:* The argument of the fitness function would be two dimensional pixels, each of which would have a color attribute (20 bits would probably be sufficient) and a depth attribute (to allow textures to be represented, perhaps another 10 bits). For such a function, N might be 10,000 x 10,000 x 30, or 3 x 10^9.
- *A Simple Tune.* 32 measures (2^5) could be time sliced into 64^{th} intervals (2^6), each of which might have 16 (2^4) possible pitch values (so as not to exceed the vocal range of inexperienced singers) plus some additional attributes signifying how the note was to be played and if it was a continuation of the previous note (2^6). For such a function, N might be 2^5 x 2^6 x 2^4 x 2^6 = ~2 x 10^6.

In considering these functions, there are a number of important points that need to be emphasized. First, the N values specified represent the number of arguments, not the number of combinations. The number of possible combinations is 2^N, creating a set of possibilities that is infinite in the practical sense. Second, the value of K is definitely not 0—that would imply, for example, that there is an "optimal" color for each dot in a painting that does not change from subject to subject. Indeed, the level of interdependence between arguments is probably quite high. If Leonardo Da Vinci had decided to make one of the Mona Lisa's eyes blue and one brown, it is doubtful that the painting would have survived the test of time as well as it has in its more consistent form. Similarly, even if you have never heard a tune before, it is often possible to detect a sour note that detracts from the overall performance.

The effectively infinite number of possible works of art in each category is not the only factor that inhibits the development of predictive scientific theory in the arts. Reliability, as previously noted, is an important contributor to the fitness of theory. In the arts, however, differing tastes across individuals leads to high variability in observed fitness for a given work—and taste changes over time can substantially influence the acceptability of an individual work. A composer writing in the Baroque style would have far more difficulty finding broad acceptance today than in the Baroque period, although it is hard to argue that the evolution from Baroque music to grunge rock actually represents an improvement in any objective measure of fitness. Moreover, the artistic fitness functions previously described apply only to original works of art; a perfect copy of a masterpiece will generally exhibit far lower fitness than the original. Thus, for the fitness function to be complete, it would need to include arguments identifying all previously created works in the same category. A history of past creations would also be useful because, under many circumstances, originality may be an important contributor to the fitness of an art work.

For all the reasons stated, no serious researcher is ever likely to attempt to determine the precise fitness function for any category of art. That does not mean, however, that research and theory do not play a role in the arts. Rather, it means that such theory tends to be directed towards achieving better understanding of the heuristic techniques that can be employed to improve fitness. Examples of areas where an artist might benefit from being informed include the properties of the medium (e.g., the behavior of stone, the underlying chemistry behind different types of cooking techniques), the characteristics of different subjects and tools (e.g., anatomy, the sounds that can be produced by different musical instruments and their associated range), approaches that can be used to create certain effects (e.g., the use of perspective in drawing, narrative devices in literature), and stylistic conventions that should nearly always be adhered to (e.g., proper spelling) along with those that should be occasionally violated for the sake of achieving realism or impact (e.g., rules of grammar).

Nowhere is the distinction between science and art more apparent than with respect to what is meant by the term "experiment". In science, the experiment is nearly always constructed in order to test the fitness of a particular theory by allowing observations and predictions to be compared. In the arts, the "experiment" involves employing an unfamiliar technique or subject to produce a work that is often radically at odds with existing works and, perhaps, existing notions of fitness as well.

Another implication of the highly rugged nature of the fitness landscape for different types of art relates to how art is studied. In the sciences, particularly where decomposability is present, phenomena can be examined in isolation and small, carefully constructed demonstrations can often be just as informative as real-world observations. When Galileo demonstrated the principles of uniform acceleration of objects by dropping two balls of different size off the Leaning Tower of Pisa then showing that they landed at the same time, the simplicity of the experiment was no obstacle to the proof of the concept—indeed, its simplicity and replicability made it all the more convincing. In the arts, however, concepts are far more likely to be illustrated in the context of a complete or major section of a work created by a master of the craft. The utility of techniques to enhance fitness is generally best demonstrated by showing how they can contribute to a complete work of very high fitness.

Table 2: Differences between art and "hard" science fitness landscapes

Characteristic	*"Hard"* Science	Art
Number of attributes	Small	Very Large
Decomposability	High	Low
Replicability of observations	High	Low
Variability of fitness over time	Low	High
Focus of experimentation	Confirm or refute existing theory	Exploration of new techniques or heuristics
Objectives of research	Understanding and predicting behavior	Identifying heuristics for assessing or improving fitness

Key differences between "hard" sciences and the arts are summarized in Table 2. In interpreting the table, we must recognize that the two columns represent the extreme end points of a continuum. While the science column might represent a plausible characterization of some of the physical sciences, as we move into the life sciences and then into the social sciences, the number of attributes grows, replicability declines, and fitness may well vary over time. Similarly, while the art column may be representative of some arts, such as painting, many artistic endeavors, such as architecture, may require equal parts engineering science and creative vision. Understanding where a particular area of inquiry, such as informing science, fits on this continuum is likely to provide important insights into the types of research that are, and are not, likely to produce valuable results. We therefore now turn to the question of how the ruggedness of a particular fitness landscape may be predicted.

Complexity and the Rugged Fitness Landscape

Synthesizing the discussions of the previous section, we might expect to see environments better described by a rugged fitness landscape than a decomposable fitness function in situations where the following characteristics are present:

1. *Numerous attributes appear to impact fitness.* Where fitness appears to be determined by a small number of attributes, the opportunities for the development of multiple peaks is limited.
2. *Attributes appear to have strong interrelationships.* Where attributes do not appear to exert the same influence on fitness in different regions of the fitness landscape, the opportunities for alternative solutions that are local maxima grow.
3. *Entities on the landscape continually adapt to improve fitness and linkages to dynamic external landscapes are present.* As noted earlier, these types of dynamics tend to favor environments where entities gravitate towards multiple peaks so as to reduce the risk of major declines in peak fitness.

Interestingly, these three characteristics closely parallel the most widely used task complexity definition in the management literature (see Chapter 7), being essentially identical to the set of characteristics that Wood (1986) proposes as the source of objective task complexity. This convergence is more than coincidental; achieving a resolution to a complex task can, itself, be visualized as finding an appropriate point on a fitness landscape—where fitness is represented by how effectively the solution meets the requirements that the task performer has been given. Thus, task performance can be viewed as a special case of the more general problem of exploring a fitness landscape. The relationship between the first two characteristics and complexity is also consistent with the writings of Herbert Simon (1981), who characterizes decomposability and complexity as polar opposites.

The Informing System Fitness Landscape

The preceding examination of landscape shapes led to two important conclusions: 1) that certain entity characteristics (i.e., many attributes, many interdependencies between attributes, dynamically changing fitness) tend to promote rugged fitness landscapes, and 2) that the nature of research in highly rugged landscapes (e.g., the arts) will necessarily differ from that suitable for decomposable landscapes (e.g., the physical sciences). In this section, we ask the question: how rugged is the fitness landscape for an informing system likely to be? The subsequent section then considers the implications for informing science research.

We begin with two assumptions. The first is that there are four key components to a basic informing system: the sender, the client, the delivery system, and the task to be performed (Cohen, 1999). It has been noted in Chapter 3 that numerous variations to such systems exist, some of which appear to be substantially more complex (e.g., multiple senders, multiple clients, and/or multiple channels). It stands to reason, however, that if fitness for the basic informing system is rugged, then more complex variations are likely to be rugged as well.

The second assumption is that informing system fitness landscapes follow the same principles identified for generic NK landscapes (e.g., Kauffman, 1993) and complexity in general (e.g., Wood, 1986). In other words, where the fitness function has many attributes, a high degree of interaction between attributes, and is subject to changes over time, we may expect that the resulting landscape to be quite rugged.

Number of Attributes

Suppose we were to attempt to define a general fitness function for informing systems of the form:

$$F = f(x_1, x_2, \ldots, x_N)$$

An obvious question to ask would be: What is the value of N? Since this question could probably not be answered authoritatively without knowing the precise nature of the function—at which point the question of the fitness of informing systems would have been "solved"—the best we can hope for is to establish an approximate lower bound. It seems very unlikely that the number of attributes impacting informing system fitness could be less than a few hundred although, realistically, it is probably much, much larger. This lower bound estimate was derived by considering the types of factors that could exert an impact on informing effectiveness for each entity in the informing system.

For the client entity, there are many areas that seem highly likely to impact the effectiveness of an informing system. These areas, in turn, each involve multiple attributes. To give some examples:

- *Motivation.* The ability to inform a client effectively will almost certainly depend on his or her desire to be informed. Such desire, in turn, would involve the satisfaction of some underlying drive or need on the part of the client. Research in the area of motivation has produced estimates ranging from 4 (e.g., Lawrence & Nohria, 2002) to 16 (e.g., Reiss, 2000) of these underlying drives or desires. Examples include the drive to acquire, to bond, to learn, and to defend (Lawrence & Nohria, 2002), as well as desires that include seeking power, independence, curiosity, acceptance, and order (Reiss, 2000), to name just some. Individuals are found to have unique individual desire profiles, specifying the degree to which each drive/desire is important to that particular person. We would therefore expect that each motivational factor would represent a separate argument to the fitness function.

- *Prior knowledge.* What a client already knows would necessarily impact the fitness of the informing system. With insufficient prior knowledge, the data that is being transmitted is unlikely to be assimilated as information. With excessive prior knowledge, the informing system is unlikely to produce much useful impact. Unlike motivation, there do not appear to be any ready-made frameworks for characterizing prior knowledge. We would certainly expect a large number of attributes would be required, such as scalar values reflecting knowledge of relevant jargon, knowledge of system operation, practical task experience, and knowledge of task concepts.

- *Cognitive preferences.* A growing literature suggests that different individuals have different preferences with respect to how they learn. Since many informing systems are likely to include client learning among their objectives, the preferences exhibited by an individual client could certainly impact the overall fitness of a particular informing system. A recent survey of learning style research identified five different frameworks that collectively would require nearly 30 distinct attributes (Hawk & Shah, 2007, p. 12-13).

Arbitrarily guessing that it would take at least as many attributes to adequately characterize the client's prior knowledge as it would to characterize each of the other two areas, it is hard to imagine that the client entity could be characterized with fewer than 60 attributes. One might reasonably expect the value to be vastly larger.

A similarly large number of task attributes could potentially impact the informing fitness. Some examples include:

- *Complexity.* Presumably, the complexity of the task component of the system would impact the fitness of a particular informing system. The review in Chapter 7 identifies at least 13 distinct task complexity constructs that had at least some support in the literature. Some of these were further broken down into a larger number of individual attributes, suggesting a total number of distinct attributes that is probably closer to 30.
- *Job design and enrichment.* The job design literature examines how the design of a task impacts employee motivation and performance. At least 5 distinct attributes (variety, identity, significance, autonomy, and feedback) are identified (Hackman & Oldham, 1976). The ability of information technology to impact these attributes in a manner that subsequently impacts system fitness has already been reported in the literature (e.g., Gill, 1996).

With respect to the delivery system, a vast number of characteristics could be required in order to capture performance (e.g., bandwidth, speed), reliability (e.g., availability, vulnerability), information formatting (e.g., text, audio, video), and interactivity (e.g., directionality of information flow, interface design). Many of these would, in turn, require many sub-attributes in order to achieve a full characterization of the system.

On the sender side, we would anticipate that a collection of attributes characterizing sender motivation to inform could potentially impact system fitness. We would also expect that a sender's *awareness of* client motivation, prior knowledge, and cognitive preferences could positively impact effectiveness in many informing situations. Thus, characterizing the sender is likely to require at least as many attributes as characterizing the client.

Beyond these component-specific attributes, we could also expect a number of general attributes might apply to the system as a whole. For example, the locus of control for informing might reside with the sender, the client, or even the delivery system (e.g., a cable TV network decides what programming to carry without being the originator of the content or the client).

What the preceding informal exercise demonstrates is that the number of attributes that could plausibly impact the informing system fitness landscape is quite large. Indeed, the number is sufficiently large—and the associated constructs sufficiently fuzzy and in need of better definition—that decades of research would be required to achieve an acceptable understanding of the informing system landscape even if it is fully decomposable. We therefore now turn to the next criteria for ruggedness: interdependency of attributes.

Interdependency of Attributes

Much like the number of attributes, precisely determining the level of interdependency between attributes in an informing system landscape requires complete knowledge of the fitness function. Indirect evidence that such interdependency could be present and an important contributor to fitness can arise from a number of sources, however. Among these:

- *Theoretical arguments.* Where theory suggests that proposed contributors to fitness should interact, then it would make sense to hypothesize such interactions as part of empirical research.
- *Empirical examples.* In depth analyses of different informing situations may lead to evidence of particular attributes contributing to fitness in different ways. For example, a variable that contributes positively in one context may contribute negatively in another or a variable that exerts strong influence upon fitness in a particular situation may have no influence in another situation.
- *Observed ruggedness.* Where the entities on a fitness space are adaptable, we would expect to see evidence of very different approaches to achieving fitness emerging, as different entities migrate towards local peaks. In a completely decomposable landscape, on the other hand, we would expect to see entities all striving towards the same peak.

We will now consider how these might apply to informing systems.

One of the strongest theoretical arguments that can be made for interdependency of attributes is the presence of variables that need to be consistent with other variables to achieve the desired effect. For example, the use of baking soda to make a batter rise requires the presence of an acidic ingredient, such as lemon juice. Many of the attributes presented in the previous section would be hypothesized to require such consistency. For example, the cognitive preferences of the client (e.g., which include attributes such as preferences for visual vs. verbal information; Hawk & Shah, 2007) should, according to theory, be matched with the information format provided by the delivery system. Indeed, nearly all of the learning style preferences would, in theory, relate to some corresponding delivery system or sender characteristic or set of characteristics. Similarly, we would expect the relative strength of different client motivational characteristics to interact with the job design attributes of the task. For example, if the client has a strong drive for control (e.g., Gilbert, 2007), we might expect that the high interactivity designed into the system would impact fitness far more positively then it would for individuals with a lesser drive for control. In the area of client prior knowledge, we could predict, with a high level of confidence, that a severe mismatch between the sender's perception of client knowledge and actual client knowledge would dramatically hamper the effectiveness of informing. Indeed, it is difficult to think of any attribute governing the fitness of an informing system that could not plausibly interact with other attributes in determining system effectiveness. Thus, on a theoretical basis, we would expect the informing system landscape to be quite rugged.

Providing a full catalog of empirical examples of reported interactions between informing system characteristics would be far beyond the scope of the current chapter, which is principally focused on considering how research in a rugged fitness landscape needs to be directed. Instead, we will need to content ourselves with a two case studies that illustrate what such examples might look like.

Both illustrations involve a unique undergraduate programming course (see Gill & Holton, 2006). The course was extremely unusual in its design, being entirely self-paced, making extensive use of multimedia and incorporating a strong peer-based learning component. In analyzing the course outcomes, two significant departures from widely observed fitness outcomes were observed. Specifically, in the research literature describing student performance in introductory programming courses two factors consistently impact learning: prior programming experience (e.g., Hagan & Markam, 2000; Holden & Weeden, 2003; Wilson & Shrock, 2001) and gender (e.g., Goold & Rimmer, 2000; Sackrowitz & Parelius, 1996). Despite having extensive data on 254 students previously enrolled in the course, absolutely no evidence of such effects could be detected for the self-paced course. Thus, the researchers concluded that nature of the course structure somehow interacted with the experience and gender characteristics so as to render them less relevant than they were for more conventionally designed courses (Gill & Holton, 2006).

A second example involves a direct comparison of the self-paced programming course with two other courses: another version of the same course programming taught by another instructor and a different course taught by the original instructor, all offered during the fall semester of 2007 (Gill & Jones, 2008). The characteristics of the three courses are presented in Table 3.

Table 3: Cross-Course Comparison (from Gill and Jones, 2008)

	Ism3232.A	Ism3232.B	Ism6155.A
Classroom Lectures	No	Yes	Minimal
Multimedia Lectures	Yes	No	No
Moderated Classroom Discussions	Optional	No	Yes
Paired Student Problem-solving	No	Yes	No
Student Presentations	No	No	Yes
Deadline Flexibility	Yes	No	No
Mandatory Attendance	No	Yes	Yes
Examinations	No	Yes	No
Outside Class Projects	Yes	No	Yes
Level of Performance Feedback	High	High	Low
Grade Subjectivity	Low	Low	High
Student Level	Undergraduate	Undergraduate	Graduate
Source	Evolved	Designed	Designed
Instructor	Instructor A	Instructor B	Instructor A
Instructor Experience with Course Subject Matter	High	Low	High
Evaluations	Outstanding	Outstanding	Outstanding

Particularly noteworthy in Table 3 are two things. First, all three of the courses were perceived to be outstanding in their effectiveness. The two courses taught by the original instructor, Ism3232.A and Ism6155.A, had both won the Decision Science Institute's Innovative Curriculum competition (in 2007 and 2005 respectively). The third example, Ism3232.B, received the second highest student evaluations in the history of the course (for which roughly 70 sections had been taught since the course's inception) the very first time that particular instructor taught it. Second, of all the course attributes in the table, there is not a single example of consistency across all three courses. In a decomposable model, this would provide support for one of two hypotheses: that none of the attributes are important or that they balance each other out—meaning that an "optimal" course could be constructed by choosing the better value for each attribute. A far more compelling explanation—supported by the history of Ism3232.A, which had experienced periods of much lower fitness in prior semesters (Gill & Holton, 2006)—is that each course is at, or close to, a distinct fitness peak arising from the interaction of its particular design characteristics.

The final evidence of ruggedness can be acquired from examining how entities are positioned on the fitness landscape. Where entities are adaptable, we would expect them to migrate towards fitness. Where they are not, we would expect less fit entities to disappear from the landscape over time. Where a landscape is fully decomposable, this process should lead to entities gravitating towards sameness, since decomposable landscapes typically have a single fitness peak. Where the landscape is rugged, we would expect to see a far greater diversity of positioning.

Once again, this chapter makes no attempt to survey all informing system fitness landscapes. Instead, we return to our university example. It has been noted in Chapter 3 that universities are, in fact, part of the academic informing system. If the fitness landscape for universities were decomposable—which would be approximately true if magazine-created rankings were accurate measures of university fitness—we would expect them to be very similar and would also expect that similarity to be increasing over time as institutions migrate towards greater fitness. If the landscape is rugged—as it would be for the hypothetical best choice fitness function as well as for other alternative functions that could readily be imagined—we would expect to see a broad distribution of missions and structures among institutions present in the landscape. Just a casual glance at the landscape of universities suggests that the second characterization is far more apt than the first. Furthermore, one can point to the growth of non-traditional institutions such as the University of Phoenix (the largest private university in the U.S. according to their web site) as evidence that diversity in the higher education space is actually growing, rather than shrinking. In fact, one would probably do better to view decomposable fitness rankings, such as those produced by *US News and World Reports*, as potential contributors to fitness—boosting student applications to those institutions exhibiting ranking improvements—rather than as measures of fitness.

Dynamics of Fitness Landscape

The final factor that is expected to contribute to ruggedness is the degree to which the fitness landscape is continuously changing. The substance of the argument is that such a landscape encourages entities to migrate to diverse fitness peaks for the sake of adaptability. The fitness benefits of changing peaks so as to achieve "optimum" fitness are also reduced, since what is optimum can be expected to change continuously.

Two important forces support the view that the fitness landscape of the typical informing system is likely to be quite dynamic. Information technology (IT) is often central to the delivery system component of an informing system. The reader should not need convincing that the pace of IT change over the past five decades has been extraordinary. Just a decade ago, transmitting video over the Internet was largely impractical except in university labs and corporate boardrooms, today it is routine. Interactive social environments, such as Second Life, providing an opportunity for rich interactions between senders and clients, are still in their relative infancy. Enabling technologies, such as XML and web services, making linkages between senders and clients much easier to establish and increasing their flexibility, have only recently begun to achieve widespread acceptance. In short, in the past and for the foreseeable future, we can expect to see technology play an important transformative role in reshaping the informing system fitness landscape.

Globalization is the second important force that can potentially transform the informing system fitness landscape. Its impact is felt particularly by the task, sender, and client entities. Offshoring and outsourcing frequently mean that systems that once needed to manage product or service production tasks must be modified towards coordinating external organizations that have taken on the production role. Perhaps even more significantly, there are many personality and motivational characteristics that appear to vary considerably across cultures (Hofstede, 2001). As informing systems expand their informing activities across borders, these factors cannot help but influence the shape of overall fitness through changing the distribution of client and sender characteristics.

Thus, we find that the typical informing system is likely to exist on a fitness landscape that is both subject to continuous change and a function of multiple attributes of high interdependence; in other words, the informing system landscape meets all the prerequisites of ruggedness.

Researching the Rugged Landscape

The arguments of the preceding section were intended to convince the reader of the distinct possibility that the informing system fitness landscape is quite rugged in shape. In this section, we address two questions relating to research in the rugged fitness landscape: (1) What happens if you make the assumption of decomposability while researching a landscape that is actually rugged? and (2) What types of research are most suitable for researching a landscape that you believe to be rugged?

The Assumption of Decomposability

From the earlier discussion of the continuum of science and art fitness spaces, it can be concluded that a decomposable fitness landscape offers numerous rewards to the researcher. Among these are:

- The likelihood that research will yield “attractive” theory, which is to say theory that is very compact in size and large in its domain of applicability.
- The ability to devise experiments that examine one variable at a time, while retaining both rigor and generalizability.
- The opportunity to take many observations, each consisting of multiple independent variables, and separate out the influence of each using statistical techniques that also provide confidence estimates for each influence, most notably those techniques derived from multiple regression.

The last of these is particularly attractive in a field research setting because such techniques can be used either to test existing theory or to discover relationships using data that can be acquired cheaply from existing sources (e.g., financial databases) or through instruments such as surveys.

As a quick review, techniques such as multiple linear regression analysis make the assumption that the fitness value—referred to as the dependent variable (F)—is generated from N characteristics through a decomposable linear process of the form:

$$F = c_0 + a_1 x_1 + a_2 x_2 + \ldots + a_N x_N + \varepsilon$$

The ε value represents error that cannot be explained even when the values of c_0 and a_1 through a_N are correctly established. Multiple regression serves to perform a mathematical computation that estimates c_0 and a_1 through a_N so as to minimize the residual error when the formula is fit to a set of actual observations.

The regression equation presumes that a_1 through a_N contribute to fitness decomposably. Where specific interactions between variables are believed to be likely, corresponding interaction terms may be introduced into the estimating equation. These are normally added only as a consequence of strong prior belief about the process. Arbitrarily introducing such terms for every possible interaction can rapidly lead to an estimating equation with so many unknowns to be computed that it exceeds the estimating power (i.e., degrees of freedom) of the observations available.

The power of multiple linear regression and related techniques makes them a staple of research in the social sciences, where developing a mathematical derivation of theory is much harder than in the physical sciences. Even where mathematically-based theory can be proposed—as is often the case in economics—the regression technique is often used to estimate actual values for the parameters contained in a particular theory. Thus, it is one of a family of statistical tools taught to nearly every social science doctoral student and its use is commonplace throughout the social science research literature.

Naturally, if a researcher strongly believes a fitness landscape to be rugged, he or she would be ill-advised to employ multiple regression analysis to determine the best linear decomposable fit to the observations. What point is there in achieving a mathematical best fit with an equation of the wrong form? Suppose, for example, you had a fitness function that mapped the list of ingredients to an objectively determined measure of "taste fitness" for all the recipes in a cookbook. If you were to do a regression on taste (dependent variable) using the ingredients (independent variables), you might find—for instance—that garlic shows a high positive significance. What would that tell you (other than, possibly, that the individuals rating the recipes enjoyed garlic)? What it would *definitely not tell you* is that you could improve your recipe for angel cake by adding garlic to it. Indeed, the whole notion of applying a technique that assumes linear decomposability to a fitness landscape that is so obviously not decomposable is preposterous.

But what about the fitness space that might be decomposable (you're not sure) or which you believe to be partially decomposable (you think, or theory tells you, that some variables will contribute to fitness uniformly across the entire fitness landscape)? In this case, the notion of employing regression-related multivariate techniques in an exploratory fashion does not seem so far-fetched.

From a researcher's point of view, what would be ideal is if we could apply low-cost techniques such as multiple linear regression to observations drawn from a particular fitness landscape and, based upon the results, make an informed judgment as to whether or not the assumption of landscape decomposability was justified. For example, we might identify attributes that we expected—either intuitively or based upon theory—to impact fitness and gather observations of these attributes with known or estimated fitness values. We could then regress the attributes (independent variables) against the associated fitness value (dependent variable). If the analysis produced statistically significant regression coefficients, we might then conclude that the decomposability assumption was valid. If not, we would be forced to conclude that the landscape was too rugged for these techniques to be useful—as was obviously the case for our recipe example.

Unfortunately, experimental evidence suggests that the results of applying techniques such as multiple regression analysis may be very misleading when it comes to judging the shape of a fitness landscape. In an investigation of statistical analyses of rugged landscapes (Gill & Sincich, 2008), a series of experiments was devised in which NK fitness landscapes of known shapes were created and then analyzed using multiple linear regression. Three different landscape shapes were considered:

- *Partitioned:* The underlying function used to create fitness values was in two parts: a linear part involving a subset of the attributes (i.e., $a_1x_1 + a_2x_2 + \ldots + a_Dx_D$) and a non-decomposable function using the remaining attributes (i.e., $f(x_{D+1}, x_{D+2}, \ldots, x_N)$, where N is the total number of attributes). In this model, variables either contributed decomposably to fitness (variables 1 through D) or were completely interrelated with other non-decomposable variables (D+1 through N)
- *Chaotic:* Fitness was determined by a non-decomposable function of all the relevant attributes (i.e.,$f(x_1, x_2, \ldots, x_N)$, where N is the total number of attributes).
- *Mixed:* Fitness was determined in two parts: by a linear part involving a subset of the attributes (i.e., $a_1x_1 + a_2x_2 + \ldots + a_Dx_D$) and by a non-decomposable function of all the relevant attributes (i.e., $f(x_1, x_2, \ldots, x_N)$, where N is the total number of attributes). This differed from the partitioned model in that certain variables could contribute to fitness both decomposably (1 through D) and through their interaction with other variables.

The paper examined the results of regressions of all attributes against the generated fitness value (no error term was used) in two conditions: 1) using original fitness values, and 2) allowing entities to migrate towards local peaks in the fitness space (as Kauffman assumed they would do). A summary of the results of these experiments is presented in Table 4.

These results suggest that landscape ruggedness could present a serious barrier to the validity of research conducted under the assumption that the underlying landscapes are decomposable. The problem is particularly severe where the underlying fitness function is partitioned such that variables exclusively contribute decomposably or through interaction. In such cases, erroneous significances on interacting variables appear side by side with accurate estimates of decomposable variables in all cases. Without knowing the underlying process, it would be easy to interpret the entire underlying process as decomposable and the spurious significances as valid. The companion paper (Gill & Sincich, 2008) explains the mathematical source of these errors and why the results cannot be treated as meaningful. The good news is that, in the absence of migration towards higher fitness, the chaotic and hybrid landscapes do not produce similar errors in estimating significance.

Table 4: Summary of experimental regression results for different fitness landscape shapes (Gill & Sincich, 2008)

Landscape	Description	Initial	During Migration To Higher Local Fitness
Partitioned	Independent variables *either* contributed to fitness decomposably *or* through non-decomposable relationships with other variables.	A large number of spurious statistically significant relationships among the interrelated variables were detected. Decomposable coefficients reproduced with perfect accuracy.	Spurious significances grew. Decomposable coefficient estimates remained accurate.
Chaotic	All relationships were non-decomposable.	No spurious coefficient estimates were detected beyond those likely to occur by chance.	Spurious coefficient estimates emerge, often highly significant.
Mixed	Some variables contribute to fitness decomposably. *All* variables participate in non-decomposable contribution to fitness.	Decomposable coefficient estimates of reasonable, but not perfect, accuracy are obtained with high significance. No spurious coefficient estimates for non-decomposable variables were detected beyond those likely to occur by chance.	Spurious coefficient estimates emerge for non-decomposable variables, often highly significant. The quality of decomposable variable estimates declines.

As soon as entities are allowed to migrate towards higher fitness, all three landscapes exhibit major errors in coefficient estimates and significances. This is largely a consequence of such migration's impact on the underlying assumption of independent observations (Gill & Sincich, 2008). If, however, we accept the argument that entities on a fitness landscape will tend to migrate towards higher fitness (or that less fit entities will not survive), these findings suggest that any results derived from the application of techniques such as multiple regression to observations drawn from rugged landscapes must be viewed with great skepticism.

The severity of the threat to research validity posed by these findings depends, to a great extent, on the origins of the theory. In some fields, particularly economics and finance, we have already noted that a great deal of the applicable theory has mathematical origins. Where statistical analysis of the sort described above is used to test such theory, we may presume that the theory assumes decomposability (since it would not make sense to apply such analysis to a landscape presumed to be rugged). This means that if the underlying landscape is actually rugged—thereby causing the results to fail to confirm precisely to the theory—the theory will tend to be rejected. Furthermore, since the very presence of ruggedness implies the theory is wrong (since the theory assumed decomposability), it seems that no particular harm is done. It might also be commented that in these disciplines, where empirical results fail to confirm mathematical predictions—as is notably the case for models of individual utility presented in Chapter 8—the mathematical theory tends to exhibit greater survivability.

A much graver threat to validity occurs in situations where theory tends to emerge as a consequence of observations, rather than from formal derivation. This approach to theory-building—which would be typical in social science disciplines such as MIS, management, and, presumably, informing science—views theory development as an iterative process in which observations are used as a basis of establishing the same theory that is later tested with empirical research. The problem arising from this process is that analytical results obtained under the mistaken assumption of decomposability will become incorporated into a body of theory. That theory will then subsequently be tested using a different set of observations gathered from the same landscape under the same mistaken assumption of decomposability; as a consequence, such tests will most likely confirm the mistaken theory since ruggedness is not the same as randomness—two independent samples drawn from the same landscape will tend to support the same conclusions.

To illustrate the problem by revisiting a previous example, suppose a researcher performing a regression on ingredient variables in recipes sampled from a cookbook discovers that the garlic ingredient variable makes a particularly significant contribution to taste fitness. Based on that exploratory research, the same researcher publishes the Garlic Acceptance Model (GAM), which proposes a causal relationship between garlic and taste fitness, hypothesizing that recipe fitness can be enhanced by adding garlic—a model totally consistent with the assumption of landscape decomposability and made even more credible should it happen to be true that the investigator loves garlic. Presuming the original sampling was done correctly, a subsequent researcher drawing another large sample of observations from the same recipe landscape in order to test the GAM will confirm the original finding, thereby adding further credence to the GAM. As this process continues, the GAM will become widely accepted. In effect, what has happened is that heuristic rules acquired through observation have attained the status of theory.

The statistical problem posed by ruggedness becomes particularly acute when the underlying fitness space is partitioned or mixed in its structure. In this case, statistically significant results are likely to be obtained for fully or partially decomposable attributes that seem quite plausible. These attributes can be characterized as the *low hanging fruit* of such research since their decomposability makes them easy to find in almost any setting. Further, statistical confirmation of their presence would tend to add credibility (at least in our own minds) to our initial results and our underlying assumption of decomposability. For example, suppose we were studying examples information system adoption and the underlying fitness landscape was rugged-mixed, with the characteristic "usefulness" contributing to fitness decomposably. If a statistical test of our observations finds that a usefulness construct is predictive of the degree to which a system is used, consistent with our expectations, we might naturally become more confident that the other significant variables we identified were equally decomposable. While our conclusions might be valid, those observed significances might also be an illusion.

Indicators of Ruggedness

As was previously stated, there is little danger of the whimsical GAM becoming widely accepted because the fitness landscape for recipes is so obviously and intuitively rugged *and* because it would be quite easy to devise laboratory experiments to refute the GAM by adding garlic to other recipes and observing consequent fitness. But the same cannot be said about many of the landscapes we research in the social sciences, where reproducing real world phenomena in a laboratory setting is often impractical (e.g., the likelihood of acceptance of a large information system within an organization) and both our independent attributes and our fitness measures are commonly latent rather than being directly observable.

There are a variety of types of evidence that could support the hypothesis that a particular landscape is rugged. These criteria include:

1. Highly dissimilar examples of high fitness can be identified; this would suggest the presence of multiple local fitness peaks across the landscape.

2. Incremental changes to fitness—resulting from manipulating the same variable in the same manner—are observed that differ significantly in different situations; this suggests that the variable's effect cannot be established independent of the values of other variables. It is also possible to observe large changes to fitness resulting from of individual variable changes, since interactions can effectively magnify the impact of such changes. For example, omitting the baking powder from a cake recipe may drastically reduce the fitness of the resulting cake, even though the quantity of the ingredient is small and its impact upon taste negligible. This differs from decomposable landscapes, where the impact of a particular variable is always the same and if many variables participate in determining fitness, the average incremental impact of each will be relatively small.

3. Fitness behavior in a particular setting that varies significantly from findings well supported by previous research; like the second, this suggests a situation-dependence that implies interactions between variables.

4. Incremental changes to individual variables sometimes appear to produce a disproportionately high impact on fitness. To explain this, consider that in a decomposable landscape each variable's impact is fixed by its range of values—a particular variable will *always* either exert a large impact on fitness or a

small impact. Where interaction is high, on the other hand, the potential impact is, in effect, magnified by the number of variables participating in the interaction.

5. The researcher's interpretation of the fitness landscape, based on observation or experience, may supply a logical basis for arguing that such interactions are to be expected.

The last of these, combining perception-based logical arguments with observed data may be somewhat unsettling from an empirical research perspective. Traditionally, we assume the needs of objectivity are best served when the characteristics of the observer appear to exert minimal impact on the observational data that we employ for hypothesis testing—an assumption justifying author anonymity and double blind peer review processes. Unfortunately, as previously noted, a high level of interactions between variables dramatically increases the coefficients that must be determined when standard statistical methods are employed. More coefficients, in turn, can easily raise the number of observations required to determine their values to levels that are impractical (e.g., tens of billions of observations in the case of 30 highly interacting variables). Thus, we are likely progress further using techniques that allow for deep study of fewer situations, such as case-based research. In such methods, the use of many sources of data, mixed with a liberal amount of interpretation by observers whose expertise must be demonstrated, is encouraged as part of a process referred to as triangulation (Yin, 1994). Indeed, some of the most influential case research has relied heavily on researcher-interpreted analysis (e.g., Allison, 1971).

To emphasize what was stated earlier, decomposable processes lead to *attractive theory*: compact, generalizable, replicable. Highly rugged landscapes, on the other hand, lead to *ugly theory*: large in size, filled with caveats, and breathtakingly hard to reproduce. Attractive theory leads to influential research publications; ugly theory—however valid it proves to be—looks as if you are making it up as you go along. The ambitious researcher would therefore be well advised to hope that the landscape that he or she is studying is largely decomposable. But what is to be done when he or she becomes convinced that the underlying landscape being studied is actually quite rugged? We now turn to that question.

Empirical Research on the Rugged Fitness Landscape

The science-art continuum presented earlier in the paper illustrates how, at the extremes, the nature of the fitness landscape being investigated can exert a sizeable impact on the objectives and conduct of research. One of the first questions a researcher therefore needs to answer about a research domain is: How rugged is it? Where the domain is extremely rugged, as it is for the arts, it is likely to be pointless to attempt to create any general theory of the domain. Better instead to focus research efforts on identifying heuristic techniques for improving fitness—as is done in the arts.

Where ruggedness is confined to a small number of identifiable peaks, on the other hand, it may be possible to develop attractive theory that is applicable to each peak. Generally speaking, any domain that has many fitness-relevant attributes and few peaks is likely to exhibit a high level of decomposability. If the researcher ensures observations being aggregated are not drawn from alternative peaks—or, to be more precise, from the fitness wells that lead migrating entities towards alternative peaks—then many of the misgivings that have been raised regarding misleading statistical results will be of less concern.

Given these considerations, an overarching goal of research on a rugged fitness landscape needs to be establishing a broad picture of the territory. As suggested by the earlier attempt to characterize the informing system landscape, this will not necessarily prove easy to do. Among the associated challenges are included:

- Identifying the set of plausible attributes impacting fitness
- Identifying the level of interrelatedness between the attributes
- Identifying possible peaks (or at least high points) in the fitness landscape
- Identifying regions of the fitness space where important variables may be treated decomposably (which may or may not correspond to peaks).

With such a map in place, the researcher can begin to answer questions regarding the generalizability of findings from a given region, the likelihood that attractive theory will emerge from broad investigations, and, perhaps, the degree to which entities have already attained fitness peaks (or perceive themselves to have attained them). This last issue is particularly important from a motivational perspective. If intelligent entities on the fitness landscape—be they individuals, groups, or organizations—perceive that they are already operating at high fitness levels, the likelihood that they will be interested in research findings related to their specific fitness function will be very limited. As a consequence, the researcher's only audience is likely to be other researchers.

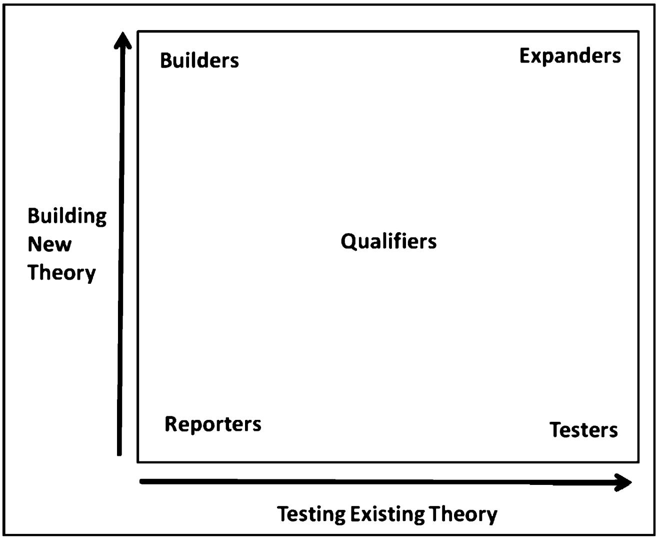

Figure 3: Theoretical contributions of empirical research (from Colquitt & Zapata-Phelan, 2007, p. 1283)

The difference in approaches between decomposable and rugged landscape research includes placing fundamentally different priorities on different research activities. One taxonomy for classifying such activities—with a particular focus on their theoretical contribution—uses the dimensions of "building new theory" and "testing existing theory" (Colquitt & Zapata-Phelan, 2007). That taxonomy is illustrated in Figure 3.

The taxonomy identifies five basic types of contribution: *builders* develop new constructs and explore relationships, *expanders* take existing theory and build upon it, *testers* verify existing theory, *qualifiers* explore the limitations of existing theory and modify the theory as necessary, and *reporters* gather observations. It is interesting to consider how the nature of the underlying fitness landscape could influence the relative importance of these contributions.

As has been previously noted, one of the most significant differences between decomposable and rugged landscapes is in regard to the nature of the theory that is likely to emerge. We would expect the perceived value of researcher roles to be influenced by a discipline's assessment of its own landscape. In decomposable landscapes, we would expect roles influential in the development and refinement of theory—e.g., builders, expanders, and testers (Colquitt & Zapata-Phelan, 2007, p. 1283)—to be particularly emphasized, since the completed theory is likely to be attractive. In the rugged landscape, we'd expect priorities to be somewhat reversed. Since such a landscape is likely to produce ugly theory anyway, those roles that seek out and describe interesting areas of the landscape—most particularly, the reporter—should be of greater significance. For example, consider the importance of the role of the reporter, also known as the critic, in the arts.

The other justification for a strong reporter role in rugged landscape research can be made in terms of our appetite for observations. As fitness landscapes become increasingly rugged, observations from one area of the landscape tell us increasingly less about what is going in other areas of the landscape. For example in an NK space of with 12 binary attributes, there are 4096 combinations leading to fitness (2^{12}). If the space is fully decomposable (12,0), using multiple regression we will likely have sufficient degrees of freedom to establish a complete and accurate map of the landscape with under 100 observations. If it is chaotic (12,11) on the other hand, we need to acquire observations of all 4096 combinations to develop a complete map—since each observation tells us nothing about similar (but not identical) combinations of attributes. In addition, if the landscape is dynamically changing, it will not be sufficient to survey the landscape once. It must be surveyed continuously if an accurate map of fitness is to be maintained.

As a consequence of the influence of ruggedness on our need for observations, we would expect that the reporter role to remain critical in such research for as long as such research is being conducted. Random reporting, however, will not be sufficient to provide useful insights into such spaces. It is quite plausible to imagine that our landscapes could be huge. Consider how our previous informal calculation suggested that defining the informing system fitness function would require a few hundred attributes at a minimum; the actual number could just as easily run into the thousands. With a domain of that magnitude, even carefully designed random sampling is unlikely to produce important insights into overall fitness. Thus, our reporter needs to be very efficient in selecting and conducting observations. We now consider that topic in greater detail.

Reporting the Rugged Landscape

One of the most important roles a reporter can undertake in a rugged fitness landscape is to identify peaks. As previously noted, the challenge that ruggedness often presents is a number of potential observations that is too large to contemplate. On the other hand, outside of the arts, we are likely to be looking at landscapes with interrelationship levels (e.g., K in the NK model) that are far less than chaotic, meaning that the number of expected fitness peaks would be well under the theoretical limit (e.g., $2^N/N+1$ for NK landscapes). Indeed, their number may be sufficiently manageable to allow all major peaks to be catalogued. Furthermore, the activity of identifying achievable fitness peaks can be very useful in situations where entity characteristics can be altered to improve fitness, as would certainly tend to be the case for the task and delivery system components of an informing system.

The obvious challenge in making and reporting observations from a rugged landscape is telling whether or not a particular entity is at or close to a fitness peak. Sometimes the entities being studied can provide useful insights. Where the entities on the landscapes being modeled are individuals, groups, or organizations, we would anticipate conscious migration towards higher fitness should frequently occur. As a result, the reporter may well be able to assess proximity to a local peak by examining the nature of the search process through which the entity reached its current fitness state. This means that a longitudinal investigation of entity fitness—acquired through examination of archival data, interviews, and other sources—may be extremely valuable. Stated another way, the study of history necessarily plays a critical role in rugged landscape research—another close parallel to the arts. It is possible to test the fitness of the predictions from a mathematically derived theory in the hard sciences without knowing how that theory evolved; the same can only rarely be said for entities on a rugged landscape.

In order to make such observations effectively, the reporter would benefit substantially from practical expertise in the landscape domain being investigated. Not only are the attributes that must be observed likely to be numerous, many will prove difficult to observe directly, such as those relating to client and sender motivation in the case of an informing system. The reporter would also need to have considerable expertise in interpreting the opinions of individuals participating in the entity being observed. The subjective opinions of individuals on matters such as causality tend to be heavily discounted where landscapes are presumed to be decomposable. Such discounting makes sense under those circumstances since decomposability implies that relationships will generalize from one situation to another. Thus, the investigator studying entities across a domain is likely to have a far more objective perspective than the individual participant. Where ruggedness is present, on the other hand, participant opinions relating to the underlying factors relevant to a particular situation are likely to be at least as valid as those of the investigator attempting to generalize from entities observed in other regions of the fitness landscape. Thus, participant opinions—however subjective—need to be elicited and carefully considered if the local fitness landscape for a particular entity is to be understood.

Another aspect of reporting that differs between decomposable to rugged landscapes is the nature of what the research is trying to accomplish. Previously, we observed that on the continuum from science to art, the emphasis of research shifts from understanding the fitness function (science) to exploring techniques whereby fitness can be improved (art). That shift, however, becomes evident long before we reach what would normally be considered arts. Looking at fields such as evolutionary biology and genetics, we see at least as much interest in investigating how migration towards fitness takes place as we do in understanding the fitness function itself. Indeed, the process of migration towards fitness is central to much of the landmark research in these domains, from Darwin's original work to Kauffman's (1993) NK landscapes and Holland's (1992) genetic algorithms. Thus, the reporter in the rugged landscape needs to be attuned both to identifying those characteristics that lead to fitness in a particular region of the landscape and to identifying those techniques that can be used to search for states of higher fitness and to transition to those states.

Other Researcher Roles in the Rugged Landscape

The preceding discussion of the importance of the reporter role might seem to imply that theory plays minimal role in a rugged landscape and that theory-intensive roles such as the builder, qualifier, and expander are therefore of little importance. That conclusion would be far from the truth. While it is true that informed observations make critical contributions to rugged fitness research, synthesis of these observations is necessary if better understanding of such landscapes is to be achieved.

Consider, for example, medicine. Although classified as a science by almost any definition, its principal domain of study—the human body—clearly exhibits the prerequisites of ruggedness: many entities (e.g., systems in the human body, each made up of huge numbers of cells), high level of interaction between these entities, and dynamically changing fitness (e.g., through the action of aging and the environment). Based upon this, we would expect to find no compact and generalizable "theory" of the human body—nor does such a theory exist. Nonetheless, great progress has been made in the field through the development of theory relating to individual body subsystems, through the direct and indirect (e.g., survey) observation of individual patients and experimental subjects, through studies of the effectiveness of past practices, through insights acquired from observing other systems, such as Fleming's observation that mold in Petri dishes was inhibiting the growth of microorganisms that led to the discovery of penicillin, and through the study of other species, such as the use of laboratory animals for experimental purposes.

One aspect of medical research that is extraordinarily different from research in many of the social sciences is an extreme reluctance to draw conclusions from data that would require making the assumption of underlying decomposability. Medicine has long recognized that interactions between attributes that impact fitness are the rule rather than the exception and that such interactions can make drawing conclusions from statistical data very risky. As an example, consider the deceptively simple question, "Is coffee good for you?" According to a WebMD article (Kirchheimer, 2004), one survey conducted over the course of 18 years involving 126,000 people found that men who had six cups per day or more experienced a reduced risk for type II diabetes of 54% (there was, however, an interaction with sex, however, since the reduction was only 30% for women). Despite the presence of incredibly strong statistical significance, the overriding conclusion was that more research was necessary. That conclusion was, in itself, amazing because the WebMD article also noted "In recent decades, some 19,000 studies have been done examining coffee's impact on health." To put this number in perspective, that single question has been addressed in a number of studies comparable to AACSB's estimate of the number of articles published globally in business and management over the course of an entire year (AACSB International, 2008, p. 10). The fact that such an extensive research effort has not led to definitive recommendations—despite the presence of high statistical significances—is a testament to the need for caution in drawing conclusions from observations gathered from a rugged fitness landscape. This reluctance also suggests a lesson for disciplines whose resources for research are vastly lower than those available for medical research (which would certainly include informing science): brute force empirical investigations of phenomena that rely heavily on statistical tests of significance are unlikely to make major contributions to our understanding of fitness where the underlying landscape is rugged; moreover such an approach may well lead to misleading conclusions.

What may be a more effective approach to research in domains of high expected ruggedness and low research budgets is to focus on mapping out the rough underlying structure of the fitness domain, using both heuristic rules acquired though observations and logical or mathematic reasoning about the various situations observed. The mapping process may include identifying both sets of characteristics associated with apparent fitness peaks and sets of characteristics that partition a space into fundamentally different fitness functions. As an example of the latter, consider the business strategy research of Porter (1980, 1985), who proposes that three generic competitive strategies exist—cost leadership, differentiation, and segmentation—and asserts that the rules for effective competition (i.e., fitness) are fundamentally different depending upon which of these is chosen.

There is, however, another interesting insight that can be gained from the coffee example. The huge investment required for such a major, and largely non-theoretical, correlation-based study of health factors demonstrates a willingness to engage in experimentation as a tool for discovering new paths to fitness and not merely for confirming or refuting a theory. In this respect, medicine has more in common with the arts than the hard sciences. On the other hand, mainstream medicine is almost totally unwilling to make assertions of causality until the underlying physical mechanism that produces the observed correlation is determined. In this respect, it is totally aligned with the hard sciences. Thus we see how the rugged fitness landscape of medicine has led to the development of an extraordinarily large portfolio of acceptable research techniques.

Social Consequences of Rugged Landscape Research

Even if a researcher accepts that a particular domain being researched is rugged, adopting research methods appropriate to the domain may entail considerable social cost if that perception is not shared by the discipline as a whole. Within the sciences, particularly high levels of prestige accompany the development of attractive new theory. Accepting ruggedness is tantamount to conceding that what theory can be developed is likely to be ugly in its particulars except, perhaps, within close proximity to local peaks (from which it cannot be generalized). Such a concession by one individual is unlikely to be greeted enthusiastically by others in the discipline not holding the same perception.

A particularly interesting case study of this phenomenon can be found in the evolution of management research over the course of the past five decades. During the late 1950s, two studies (one conducted by the Ford Foundation, one conducted by the Carnegie Foundation) were sharply critical of U.S. business schools, with particular emphasis on the unscientific nature of their research. At the time, the most common form of research was the in-depth case study—a form of research closely corresponding to the likely output of the previously described reporter research role. The Ford Foundation report, for example, asserted:

> Case collection is an important activity for the business school, both because of its contribution to teaching and because of its value as training for the faculty member. But case collection by itself is not research in the usual sense of that term. It can, however, become the raw material for research since, through careful and discriminating analysis, significant generalizations can sometimes be drawn from the study of a large number of cases. (Gordon & Howell, 1959, p. 385)

During the 1960s and 1970s these two reports, augmented by associated funding opportunities, exerted an extraordinary influence on the nature of business education and research (Khurana, 2007; Mintzberg, 2004; Starkey & Tiratsoo, 2007). Of particular note, the twin notions that reporting was not research and that the objective of research should be generalizations (i.e., theory) drawn from many observations—both evident in the preceding quote from the Ford Foundation—were clearly taken to heart. For example, by the year 2002, the reporter-type research that dominated the field in the 1960s (representing roughly 2/3 of articles in 1963 and 100% of articles in 1966) had entirely disappeared from the prestigious *Academy of Management Journal* (Colquitt & Zapata-Phelan, 2007, p. 1291). In gauging the significance of these numbers, it is also worth noting that the Academy of Management's other top-rated academic journal, the *Academy of Management Review*, is exclusively devoted to theory development. In fact, management's obsession with theory-building has become so extreme that even influential researchers in the field have started to complain about it. One such researcher used the example of the epidemiologist who first identified strong correlations between smoking and health problems in the 1930s, asserting that had that epidemiologist been in management field today, he would have been unable to publish his findings owing to their lack of theory-based justification (Hambrick, 2007, p. 1348). In stark contrast, we have already seen that the medical community is perfectly willing to gather and report observed findings and sometimes even recommend actions based upon particularly strong observed associations (e.g., prescribing medications for off-label uses). What they will not do is accord such findings the stature of being theory.

What is particularly extraordinary about the management discipline's devotion to theory is that it coexists with a nearly complete failure to inform practice. For example: (1) on one list identifying the fifty most important management innovations, not one originated from academic research (Pfeffer, 2007, p. 1336), (2) many of the most significant findings of human resources (HR) management research are widely disbelieved by HR managers (Rynes, Giluk, & Brown, 2007, p. 988), (3) managers use far more tools developed by consultants or other companies than tools developed by academics and they are also happier with those non-academic tools (Pfeffer & Fong, 2002, p. 88), and (4) important management ideas are most likely to originate in practice and then flow to academia, rather than the other way round (Barley, Meyer,

& Gash, 1988) . In short, the concerted attempts by management research to describe its landscape with attractive theory have not offered sufficient benefits to attract the attention of practitioners. That would, of course, be the expected result if the underlying landscape being researched is actually rugged, since attractive theory would probably not be particularly useful in guiding managers towards greater fitness under such circumstances.

Aside from the loss of prestige associated with reporting rather than theory-building, the skills necessary to be an effective reporter-researcher are also quite different. Earlier, it was pointed out that the effective reporter in a rugged domain would benefit from being a practical expert. The core of this argument is that there are likely to be far too many possibly relevant variables to establish values for all of them in a particular setting. Thus, the reporter needs to be selective, much like the doctor deciding what tests to run during the course of a complex medical diagnosis. That implies that researchers must possess considerable expertise in domain practice and also training in research techniques appropriate for in-depth data acquisition in the field. Such training is likely to be very different from that associated with educating researchers for a career of theory building and the analysis of large data sets. The mismatch between acquired and desirable skills represents a formidable barrier to changing research philosophies. It is, perhaps, part of the explanation for why disciplines historically cling to their existing research paradigms long after their shortcomings in explaining their research domain have been exposed (Kuhn, 1970).

Conclusions

The general goals of this paper have been to argue: 1) that rugged fitness landscapes represent a very different research domain from decomposable landscapes, 2) that numerous attributes, interrelatedness of attributes, and dynamic changes to fitness all contribute to landscape ruggedness and, 3) that the objectives and approaches to research that are appropriate are heavily influenced by the ruggedness of the fitness landscape. Specifically, decomposable domains lead to attractive theory that compactly describes large regions of the fitness landscape; rugged domains lend themselves to indentifying techniques for improving fitness since the underlying theory describing such domains is ugly—too large and with too many exceptions to be particularly compelling.

In the specific context of informing science, the following arguments have been made:

- The building block of informing science, the informing system, meets all the prerequisites for rugged landscape, i.e., many interacting elements in a dynamically changing environment.
- In the presence of such ruggedness, certain types of research approaches—particularly those that emphasize gathering rich observations of individual systems along with the history of their evolution—are likely to be more valuable to the discipline than a preoccupation with theory building.
- Where disciplines accept the fact that their underlying landscape is very rugged, research techniques consistent with the underlying landscape can be developed and research can make major contributions to practice. Medicine provides an excellent example of such a domain.
- Where disciplines ignore evidence of domain ruggedness and persist in efforts to construct attractive theory, they are likely to experience almost complete disinterest from the practitioner communities that they attempt to study. The field of management may represent one example of this phenomenon. MIS, the discipline most closely related to informing science, has experienced similar disinterest (see Chapter 3).

Despite the challenges presented by the rugged fitness landscape, tailoring a research approach to fit the landscape offers some distinct advantages as well. Whereas empirical research into decomposable systems tends to reward statistical acumen and data collection, the rewards for research in the rugged landscape accrue from immersion in that landscape and its processes; the statistical analysis that occurs once the rugged landscape has been mapped out is largely confirmatory in nature. In order to speed your research program—since time will be very much of the essence in most rugged landscape research—you will need to enlist the active assistance of the participants in the system you are researching; their role will be that of equal partners in your research, rather than subjects. As a natural consequence, the knowledge that you acquire will be of a type that is palatable to the individual, group, or organizational entities that inhabit the landscape being studied. The type of bottom-up research that leads to progress in understanding a rugged landscape produces, as a byproduct, a collection of stories and examples that communicate well to students and experts alike. Thus, there will tend to be an appreciative audience—outside of other researchers—for your findings. Furthermore, once you develop an appreciation for the entirety of a rugged landscape you are unlikely to become fixated upon the behavior of a particular specialized peak. In consequence, you are far less likely to find yourself proposing theories that generalize poorly or which provide highly efficient but brittle solutions that cause entities to fail in the face of a changing landscape.

Studying rugged landscapes, and recognizing them as such, will also tend to chip away at the silos that so often separate research disciplines. Particularly where informing is involved, attributes of different components in the informing system will participate in the non-decomposable relationships that lead to ruggedness. If we are to have any hope of better understanding these processes, it therefore follows that researchers with fundamentally different domains of expertise (e.g., task experts, experts in psychology, experts in technology, and experts in education) will need to work together in understanding how the various attributes interact. A single perspective or research paradigm will simply not be sufficient.

Sadly, the findings of the rugged landscape researcher will not be pretty. Fortunately, their potential for positive impact on the landscape being studied should more than compensate for their ugliness.

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Chapter 13

Use and Redesign of Informing Systems: Lessons to Learn from Philosophizing and Practicing

Hans-Erik Nissen

Introduction

This chapter discusses how to describe the transdiscipline of informing science and its framework in a broader way. Behind this lie three concerns. The first is that the aim of informing oneself and others today concerns both the work and the lives of people. The second is to recognize informers and clients not only as performers of particular tasks but as whole persons interacting with others. The third is to recognize informing science not only as an academic field but also as practice. The chapter will largely focus upon how to meet these concerns by broadening the informing science framework.

By way of background, Chapter 22 (Cohen, 2009) gives the following sentence definition of informing science:

"The fields that comprise the transdiscipline of Informing Science

- provide their ***clientele*** with ***information***
- in a ***form***, ***format***, and ***schedule***
- that ***maximizes its effectiveness***. "

The concept 'transdiscipline' Cohen (2009) explains as: "A transdiscipline is a coherent set of research topics that are shared by several distinct academic disciplines." In this chapter, however, I will adopt the view that a transdiscipline involves investigators, from different backgrounds, who jointly develop and *use a shared framework to investigate some topic*. This perspective is summarized as follows:

Transdiscipline

Within many fields, such as medicine, biosciences, and cognitive science, there is as growing awareness of the need for transdisciplinary approaches. Likewise, engineering education and research needs to be supplemented by a fundamentally new way of addressing the multidimensional, complex problems that society faces today.

. . .

In following the transdisciplinary concept, researchers representing diverse disciplines work jointly to develop and use a shared conceptual framework that draws upon discipline specific concepts, theories, and methods, but addresses common problems through a new synthesis of common ontology, [epistemology], theories, models, and methodology. (Text within square brackets added by the current author.) TheATLAS (2008)

Cohen (2009), in Chapter 22 Figure 5, proposes a conduit framework that could be shared by investigators in studying informing systems. This framework shows a linear transmission of messages from an informer to a client. The principal goal of this chapter is to propose a more general framework and to explain why this framework may better serve the needs of our research and its application to practice.

The chapter begins with the section "Fundamental assumptions of an Informing Science Framework". Here, I discuss various assumptions stated by Cohen in the subsection "Cohen's informing science framework". The later subsections "Towards a framework suitable for guiding research" and "An alternative framework" then present an overview of an alternative framework and some of its assumptions. Most importantly, I will argue that an adequate framework has to include circular chains of determination.

I next turn to the subject of epistemology, that is, methods of becoming more knowledgeable about specific topics. Chapter 22 suggests that informing science researchers should study how clients become informed through diverse epistemologies. Although there exist many schools of epistemologies, focusing too much on this diversity may cause us to overlook the point that all epistemologies, by and large, fall into one of two clusters. These differ considerably between each other, but show internally only minor differences. I have titled this section "Scientific Traditions and Social Science Studies". I conclude the section with a subsection titled "Assumptions about rationality of whole human beings". Here, I specifically consider the issue of "human fragilities of both the informer and the client." as referred to in Chapter 22 in the caption to his Figure 5.

In my suggested framework I will focus on whole, living human beings exhibiting a variety of strengths and weaknesses. This will become apparent in the sections "A generalized framework" and "Details of a broader framework" that precede the chapter's final conclusions.

Fundamental Assumptions of an Informing Science Framework

Cohen's Informing Science Framework

The framework for informing science espoused in Chapter 2 (Cohen, 1999) and its philosophy in Chapter 22 (Cohen, 2009) has served many valuable purposes. It has identified a common set of problems that are encountered in many disciplines. It has provided some vocabulary (e.g., informing system) useful in describing aspects of these problems. It is simple enough so that individuals in diverse disciplines can readily comprehend the unifying themes of the field. All of these have contributed to the rapid development of informing science over the past decade.

In considering the Cohen framework, however, we must also recognize that it was never intended to serve as a unified model of informing intended for direct application by researchers across many disciplines. For example, the model of communication presented was based upon the signal transmission path shown in Shannon and Weaver's (1949) model as both unidirectional and linear:

Sender → Encoding → Transmission → Decoding → Receiver

Researchers in the informing science field obviously do not view these as essential characteristics. In Chapter 3, for example, Gill and Bhattacherjee, for examples, present the informing science framework, using bidirectional arrows and outline many alternative pathways. Cohen (2009) also indicates informing science will have to consider informing networks. Any fruitful investigation of such networks will necessarily include circular chains of determination, as I will later argue in this chapter.

Chapter 2, Cohen distinguishes three levels of abstraction in studying informing systems:

- the implemented system [in use],
- plans for implementation,
- creation of plans.

(The text in square brackets added by the author of this chapter.)

Chapter 22 returns to these three levels, which he now sees as suited mainly for studying and analyzing how to inform people in relatively routine work tasks:

- the informing instance level, where actual informing takes place,
- the instance-creation level, where new informing instances are created,
- the design level, where general patterns for informing are established.

The extent to which Chapter 22 points should be taken to supplant rather than supplement Chapter 2 points remains unclear. I would suggest that Cohen's levels of abstraction are more constructively construed as different domains within which informing systems may be observed, analyzed, and/or explained.

Cohen and others treating complexity

Chapter 22 states: "… As complexity grows, however, distinctions between levels are likely to blur and new patterns of informing and informing systems evolution are likely to be required. …" Gill and Cohen (2008, pp. 149-150) discuss task complexity. The most widely used definition is that of objective complexity (see Chapter 7), which asserts: "A task's complexity is determined by the number of task elements, the degree of interrelationship between task elements and the degree to which task objectives are changing…"

The two first characteristics correspond to what Senge (1990) calls "detail complexity". Mentioning the degree to which task objectives change does not seem to meet what Senge (1990, p. 72) calls "dynamic complexity". He makes the following important distinction: "*The real leverage in most management situations lies in understanding dynamic complexity, not detail complexity*… Unfortunately, most "system analyses" focus on detail but not dynamic complexity. Simulations with thousands of variables and complex arrays of details can actually distract us from seeing patterns and major interrelationships…" Cohen (2009) in the section "Areas for Future Research" mentions that "… the problems of dynamic complexity often fall outside the domains of existing disciplines…" However, he does not discuss how these problems could be handled in his framework.

Complexities relevant to an informing system may derive from its intended scope of operation, procedural requirements, available data, or situational circumstances. Examples can be illustrated with Eriksén's (1998) study of public service one-stop shops in Sweden. A typical citizen may not know which public office can answer a question or give guidance on an issue. Starting in the 1990s many Swedish municipalities introduced a single facility where a designated 'generalist' office clerk can advise citizens on relatively simple questions for which they otherwise would have to consult one or more special branch offices. The clerks in the one-stop shops could answer a number of questions within the realm of different branches of the municipal administration, including tourism, social security, employment, and police matters.

Eriksén found on the one hand that the managers of the special branch offices believed that the tasks of the clerks in the one-stop shops would be simple and routine. On the other hand she found, closely following what these clerks actually did, that their work tasks were very complex. To put it in Eriksén's (1998, pp. 110-111) own words:

> "… Although the aim was always to take care of questions and problems on the spot, sometimes this was not possible. … While going through the video-recordings … I saw several instances of problems which took hours or days to solve. It wasn't that it actually took hours or days of concentrated work with that specific problem, it was usually a matter of keeping it at the fore – thank God for Post-its! – while trying to get hold of someone who, for a reason or another, needed to be consulted in order to solve the problem. In most of these cases, the visitor or caller who needed help was not aware of the actual time delay. The generalists were professional about giving good service, and would usually close a service about an

unresolved problem with a reassuring '*We'll take care of it for you*', or, '*We'll get back to you within the next few days with an answer*'. But the work involved afterwards might well be spread out over several days and involve many unsuccessful phone calls before the problem was fully solved. "

Eriksén (1998, p. 121) also found that the generalists had a variety of data resources, with the computer resource having its own complexities:

> " The trick is to keep in mind that the people can be marvelously versatile and communicative nodes in information networks. It's not so hard, really, once you begin to focus on work practice. Consider the view from the observer's seat, in a corner behind the reception desk. The computer screens sit there on the desk beside each work space, unresponsive unless directly addressed, and even then they can be tough to get a straight answer out of. But look again – the computers are surrounded by binders, books, time-tables, piles of paper, telephones, Post-its and other notes taped on the wall, personal calendars , note-books, catalogues, manuals, brochures, maps. And besides all the different artifacts, there are almost constantly on-going activities and dialogs, and the people passing by the front desk on their way into or out from the back offices."

The work tasks of the clerks at the front desks also became complicated by frequent interruptions. In her studies Eriksén (1998, p. 117) found that existing computer programs were not designed to support such work:

> "… And we noted that none of the computer applications in use appeared to have been designed to support interruptable work in any way. Some of them, especially older mainframe based systems, were real nightmares in this aspect, as they were textbased and had to be entered completed screen by completed screen. Repeated interruptions in working with this kind of updating would almost inevitably lead to loss of information and the need for time-consuming checking of what had actually been updated and what needed to be redone. Yet some of these older systems offered a broader and more

coherent over-view of the work at hand than the modern graphic interfaces. "

This section on treating complexity illustrates some points of difference between Cohen's framework and the one presented in this chapter. First, Senge's view on dynamic complexity illustrates the importance of explicitly including time and time delays among the fundamental assumptions. Eriksén's report on how her generalists handle delays caused by a need of further investigation before they can answer a citizen's question illustrates the same point. Second, what Eriksén reports, illustrates the need to assume people to be whole human beings showing strong sides, not only fragility. Third, the quotations from Eriksén illustrate the distinction, mentioned above and discussed below, between informing systems and various kinds of artifacts. Next I will start to present an alternative framework.

Towards a framework suitable for guiding research

Figure 1 will present an overview of an alternative informing science framework. It differs from Cohen's framework, for instance, in the following respects:

- it includes circular chains of determination,
- it distinguishes three domains of observation, analyses and explanations,
- it explicitly presupposes people to be whole human beings,
- it explicitly introduces time and time delays.

In the following text I will sometimes use "closed cause-effect chains" as a synonym to "circular chains of determination".

An Alternative Framework

A generalized framework

Figure 1 in a sense could be seen as a step towards a meta-model of fields studied by informing science. The suggested framework differs from that of Cohen (1999, 2009) in the sense that its assumptions put fewer restrictions on inquiries undertaken than does Cohen's (2009) framework, explicitly or implicitly. The objective of this is to release restrictions on empirical data to gather and analyze. For instance, the humans in Figure 1 are not restricted to behave as maximizing economic men. Hence, more data have to be collected on how they behave and why. Here unequal distribution of limited resources and power between groups of people will enter. These data will need different kinds of analyses than those found in classical economic theories of the firm populated by economic men. Thus, the proposed framework potentially broadens the findings of inquiries. The words "generalized" and "broader" framework I will use as synonyms.

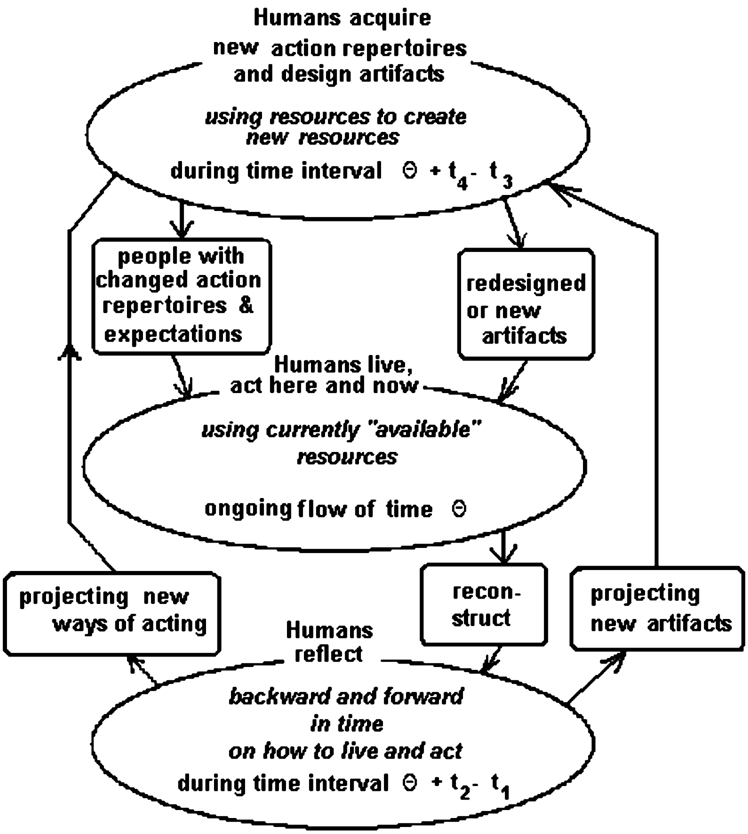

Figure 1: Overview of an informing science framework.

In other words Cohen's framework offers a tool for communicating what the field of informing science is about. My framework I offer as a tool for guiding research within the emerging transdiscipline of informing science.

A linear chain of determination starts with a "cause" and ends with an "effect". A circular chain of determination opens alternative ways to assign "cause" and "effect". The directed arrows in the figure show two different circular chains of determination.

Practitioners, rather than academic teachers and researchers, will have most experience in the central domain. There they live and act in their professions. This they mostly do in an ongoing here and now restricted by limited resources available to them. These resources will differ between different groups of people and professions.

This will be the case both on local and global levels. The amount of resources available will influence humans' action repertoires and expectations. What they most urgently need to inform others about, or become informed about, will be contingent upon resources available to them. This presents a perspective on informing that falls outside Cohen's framework. However, it will be a perspective that researchers from political science would raise.

Learning and designing in the domain that creates new resources will also need substantial resources to realize project ideas. Churchman (1971, p. 47) identifies three kinds of individuals, who need to become involved in system design: the client, the decision maker, and the designer. Cohen (1999, 2009) distinguishes clients and designers. The latter are only implied behind what he writes about designing. Through his resources, Churchman's decision maker influences the outcome of the processes of design and learning. Decision makers as controlling resources are not explicitly discussed by Cohen. In practice tensions between clients and designers on the one hand and decision makers commanding resources are abundant. Churchman (1971) assumes that the designer shares the value preferences of the client, but that these preferences will not necessarily be shared by the decision maker. Whose value preferences designers choose to share in practice, remains open to empirical investigations. The framework in Figure 1 makes the dilemma of scarce resources explicit.

Figure 1 presents human beings as living, not only as performing tasks that are probably assigned to them by others. The two different circular chains of determination indicate (1) the processes by which human beings unlearn and learn changed ways of acting and (2) those by which they design /redesign artifacts and act with respect to those artifacts as resources.

Figure 1 shows people reflecting as a domain separated from the here and now in which they act. The reason is that reflecting always occurs after or before the ongoing act (Schutz, 1967, pp. 45-47 and p. 57). Starting to reflect will often be triggered by a difference between an expectation, conscious or not, and the outcome of an action. A domain of reflecting is not explicitly addressed in Cohen's framework.

In a sense events occur in all three domains in parallel. However, tracing the relevant aspects of a particular activity necessarily requires focusing on different domains at different times. To become aware of this fact is my reason for introducing time and time intervals.

For the times shown in Figure 1 the following inequality holds $t_4 > t_3 > t_2 > t_1 \geq 0$. The time intervals explicitly focus on the time delays between acting and reflecting and between projecting and acting to create new resources. Senge (1990, p. 89) writes: "As we've seen, systems seem to have minds of their own. Nowhere is this more evident than in delays — interruptions between your actions and their consequences. Delays can make you badly overshoot your mark, or they can have a positive effect if you recognize them and work with them."

Informing versus information systems

Making a distinction. In the suggested generalized informing science framework I always refer to whole human beings, when I write about "humans". This entails that they never are fully controlled from outside in the ways they interpret their experience and in the ways they act.

In what follows I will write about informing systems in the sense explicated below. Systems supporting automatic control of machinery should be called "automatic control" or "data processing" systems. Infrastructures that enable automatic control of message transmission and enhance data security illustrate cases of information systems. Informing systems do not need to entail computers. Otherwise, all comparisons with how people informed themselves and each other before the advent of digital computers would be excluded. Moreover, to avoid misunderstandings I suggest researchers in informing science should not use the equivocal acronym "IS".

Informing system	**Information system**
The concept of an 'informing system' I delimit to include closed cause-effect chains that comprise at least some human being. Consequently how they interpret data and how they act will not be fully predictable.	In information systems closed cause-effect chains are confined to artifacts - for instance, systems dedicated to support automatic control of machinery. Systems controlling ignition in cars, industrial robots, etc. offer examples of this kind of systems. Short of breakdowns they are fully predictable.

Langefors (1966, p. 171) argued and more extensively discussed in Langefors (1995, pp. 144-148) that data have to be interpreted by people. This people do using their pre-knowledge acquired through earlier experience. (Langefors' "pre-knowledge" I would call "experientially acquired expectations".) Based on this insight Langefors (1995, p. 56) writes:

> " It is natural to say that an "information system" is a system in which essential components are information entities or information processes… we know that a set of data cannot be an information entity except when it is combined with requisite pre-knowledge and an interpretation process. Thus, to have an information entity, we will have to have, for instance, a person plus some data."

This indicates that Langefors' in what he called "information systems" entailed people. His use of this term corresponds to what I have suggested to call "informing system". Unfortunately the way he conceived "information systems" has been misunderstood. (Langefors, 1995, pp. 52-55). The reason was that his distinction between the concepts 'data' and 'information' were blurred. This distinction will be discussed further in the section "Some assumptions about human communication" below.

Lately the field of information systems has broadened to subsume also journalism and education. In these fields it seems appropriate to talk about informing systems rather than information systems. This shift in terminology offers four advantages. First, it characterizes the informing system as something people create to inform themselves and others. Second, people have done so for thousands of years. This opens an opportunity for historical comparisons. The roles of both social and cultural contexts and technologies, other than computers, then can be considered. Third, it also allows for people *interpreting* data they gather or receive to inform them. However, the informee's interpretation might differ from the one the informer intended to achieve. Fourth, changing informing systems today will generally entail taking advantage of new affordances offered by communication and computer technologies. The term "information system", coined in parallel with computers, plays down the role of people involved in their use. Information systems experts, as designers and company experts consulted during requirements specification, then become the people who count, relative to those people who will actually use the resultant computer support. The term "informing systems" opens up a possibility for studying people who use them at least as much as those involved in their redesign. Moreover, in their work and life situations people should be studied as professionals in their own right.

Finally, the above distinction between informing and information systems brings the following tacit assumption into the open. Advocates of technical solutions to all problems seem to assume that artifacts always are more dependable than human beings. This, however, presupposes that the situations artifacts encounter will fall into those presupposed by their designers. Human beings in informing systems, particularly if encouraged and entrusted to do so, might reinterpret situations as novel and invent new ways of handling them.

Tasks discussed as unproblematic also misses the fact that they generally have to be performed in face of unexpected situations. Recognizing this underlines the need to support both planning and handling situations that evolve in unforeseen ways. What it takes to keep well informed in such situations Weick and Sutcliffe (2007) have studied in *high reliability organizations* (HROs). They have summarized their findings in a number of principles of which the first three are: (1) "HROs are distinctive because they are *preoccupied with failure*. They treat any lapse as a symptom that something may be wrong with the system, something that could have severe consequences if several separate small errors happened to coincide." (2) "Another way HROs manage for the unexpected is by being *reluctant to accept simplifications*. It is certainly true that success in any coordinated activity requires that people simplify in order to stay focused on a handful of key issues and key indicators. But it is also true that less simplification allows you to see more." (3) "HROs are *sensitive to operations*. They are attentive to the front line, where the real work gets done. The 'big picture' in HROs is less strategic and more situational than is true of most other organizations" (pp. 9-12.)

Later in their text Weick and Sutcliffe (2007, pp. 63-64) elaborate and motivate these three principles somewhat more:

> Anticipation, which involves tracking the development of unexpected events, is done more mindfully when practices are preoccupied with failure, reluctant to simplify details, and sensitive to operations. The first principle involving failure is based on the assumption that gradual, interconnected development of unexpected events sends weak signals of this development along the way. A preoccupation with failure catches these signals earlier, when it is easier to correct them and learn from them. It is emphasized that success also has liabilities and may produce failures such as overconfidence, reduced safety margins, and elimination of redundancies. The second principle involving simplification is based on the assumption that the diagnostic value of weak signals is lost when those details are lumped into crude, general categories. Categories may improve coordination, but they harm detection of events not seen before. The third principle involving operations is based on the assumption that plans and design reflect intentions that are rational but context-free and can be implemented only if context-sensitive experiential rationality is applied to them. Sensitivity to operations takes the form of interpretive practices that doubt the applicability of intentions and then discover ways to transform the intentions into meaningful actions in a specific context.

Establishing informing systems. The last phase of designing or redesigning an information system generally is called implementation. However, when it comes to what I have suggested to call informing systems the concept 'implementation' would mean that somebody from outside changed the way people act. This contradicts my assumption of whole human beings as not controlled fully from outside. In

Nordström (2003) I have found a resolution to this terminological dilemma. Nordström (2003, p. 127) writes:

> … We frequently talk about implementing "information systems" but I do not see this as adequate to talk about implementing informaction systems. Using the embryonal theory introduced here, implementation will have to be confined to IT-artefacts. They can be designed and implemented. When it comes to informaction systems I suggest that such systems *become established* rather than being designed and implemented. The differences in the connotations of the terms "establish" and "implement" highlight features I find important and want to stress. The most important difference is that implementation of an IT-artefact does neither imply that it is used, nor, if used, how this is done. Usually it refers to the fact that a program, or a system of programs, has been installed on a computer … Now the fact that a program is technically implemented on a computer does not mean that we have an informaction system. The distinguishing criteria for informaction systems are… the co-production of organizational actions by the IT-artefact and some organizational agent… This process of acknowledgement lies in the hand of the organisational agents and not in the hands of the designer of the IT-artefact.

Nordström (2003) assumes that his "informaction systems" include whole human beings as actors. They correspond to what I refer to as informing systems. For the reasons given by Nordström I suggest to say that by co-evolution of people and IT-artifacts informing systems become established.

In establishing an informing system I include the unlearning and learning of the human actors and also their acquiring of some new action repertoires. While establishing an informing system some data processing systems may be implemented or made newly or differently available to target users.

This warrants adding the following assumption to the framework proposed in this chapter:

- informing systems become established by the ways people use them, not by the ways external experts implement automatic data processing systems they may entail

Where do informing systems enter in Figure 1? Looking at Figure 1 no informing systems can be seen. In all three domains we find activities by which people inform themselves or others. These activities, however, constitute integral, inseparable parts of activities with a broader scope. The informing systems have to prove their value by how they contribute to the broader activities. The domains in Figure 1 explicitly focus on these broader activities, but also imply a number of informing systems. In choosing this focus I choose a similar primary focus as Langefors (1995, pp. 99-101), who focuses on broader systems served as "object systems", and Checkland (1981, pp. 115-122), who primarily focuses on "human activity systems".

Having presented the essentials of the alternative framework, I now turn to a more detailed examination of its conceptual underpinnings.

Scientific Traditions and Social Science Studies

Two Schools of Metascience

Table 1 compares important assumptions of the two research traditions, which Radnitzky (1970) distinguishes.

In the English speaking world the word "science" generally refers only to natural sciences. In this chapter I will use the words "science and scientific" in a broader sense encompassing social and cultural sciences as well.

In informing science research guiding interests should guide choice of methods of inquiry and how they are used. Radnitzky (1970, Vol. II, pp. 5-13) distinguishes five research guiding interests:

- The technical – support of work.
- The hermeneutic – mediation of tradition.
- The emancipatory – critical, i.e. freeing consciousness from its dependence upon hypostatized forces.
- Improving the world-picture.
- Improving the reflection on existential themes.

In the transdiscipline of informing science combinations of two or more research guiding interest will generally be involved. Traditional information systems research has been dominated by a technical research guiding interest.

Table 1: Main differences between LE and HD traditions.

LE schools assume:	**HD schools assume:**
to state objectively true facts about an observer independent reality;	to state intersubjectively sharable relations between observers and a domain;
that historical contexts are irrelevant; (synchronic observations)	that historical contexts are relevant to data collected; (diachronic observations)
that only values intrinsic to science shall guide research;	that both science intrinsic and extrinsic values shall guide research;
that theory and practice can be strictly separated;	that theory and practice are mutually related;
that language used should be extensional and denotational;	that language used should be seen as mainly intentional and connotational;
that they form the bases for technologies and emancipate man from nature;	that they support understanding, mediation of traditions, and emancipation by improved self-understanding;
that the task of scientists is to produce findings valid according to the correspondence theory of truth.	that the task of scientists is the growth of knowledge according to coherence theories of truth.

Researchers of these two metascientific schools will start from the set of assumptions into which they have been socialized. Working in transdisciplinary research programs they will have to acquaint themselves with assumptions of the other tradition. Researchers in informing science even might profit from studying and discussing the assumptions for a broad framework presented in this chapter.

As whole human beings, we want to know more and to build future societies and lives for us and our children. Researchers who entered their careers under both the LE and in HD traditions will be needed to contribute to this growth of knowledge.

A need for supplementing LE methods of verification was foreshadowed in Giambattista Vico's work from the beginning of the 18th century. He contested Descartes' method of verification (through logical deduction from axioms derived from observation) as universally applicable (Stanford Encyclopedia of Philosophy, 2007, section 3.). He did not argue that the Cartesian method was irrelevant. His position was that other methods were needed for studies that extended to civil societies. These methods had to account for history and language including rhetoric and use of metaphor. According to Vico, knowledge in human sciences is verified not through logic but through creation. This is known as his principle of *verum factum.*

Galtung's View on Social Science Studies

Galtung's ideas about social science studies, stressing potential worlds, are reminiscent of Vico's views on creation and invention. Galtung (1977, p. 57) distinguishes three types of sentences in research: (a) data sentences, (b) theory sentences, and (c) value sentences (external to science). Galtung wrote at a time before it was common to acknowledge the importance of values external to science in information systems studies. He thereby exposed the connection between methodology and ideology. He also introduced the important distinction, discussed below, between invariance seeking and invariance breaking.

Traditional empirical science, according to Galtung (1977, p. 51-56), only compares data sentences and theory sentences. If they show dissonance data sentences are perceived as stronger than theory sentences. A dissonant theory sentence (hypothesis) is discarded as false or revised for further testing against new data sentences. What Galtung calls traditional science belongs to what above was presented as a science applying LE criteria of validation. For studying civic life and societies such an approach functions as a straitjacket preventing the researcher from reaching out to examine values.

Data and theory sentences have descriptive power within what may be called two "dimensions" or two "worlds" of reference - i.e., what is empirically observed and what is theoretically foreseen. What is observed or foreseen is not necessarily preferred (Galtung, 1997, p. 56). Hence issues of preference (criteria, norms, policy, etc.) cannot be addressed within these two dimensions. One way to break out of this straitjacket is to add *value sentences*. By introducing these, a third dimension, of *preferred* worlds, is added to the earlier two dimensions. Thus one establishes a basis for addressing what is preferred in addition to that which is observed and that which is theoretically foreseen.

A preferred world situation currently may not exist. To adherents of traditional empirical science possible worlds coincided with the empirically known or theoretically foreseen reality. Applied to the fields of social science this leads to theories of a stable status quo or change following known laws. Galtung's trilateral form of science presumes a potential reality broader than known empirical reality. Further, invariances in social science contexts have to be approached (and accounted for) differently than invariances found in natural sciences (pp. 68-71).

Galtung (1977) devotes a chapter to what he calls "Science as Invariance-seeking and Invariance-breaking Activity". A proposition is a statement relating a number of variables. It has to be based on a valid data sentence and a valid theory sentence. To become complete the conditions under which it holds have to be specified. If it holds under changes in other variables than those included in the relation, it is said to be invariant.

The inclusion of a value dimension in science provides the basis for distinguishing two attitudes to invariances. The difference between these and their scope of application is best illustrated by a quotation:

> ... For any invariance is here considered as an ideological statement, however much it is produced under the banner of value-free, "objective" science. ... A sentence, whether based on data sentences or theory sentences, or both, *excludes* something. A value sentence, whether based on a goal or an interest, *includes* something, that which is preferred. As long as what is preferred is also observed and/or foreseen by data or theory, there is no

> problem. However, the moment what is excluded by data and/or theory is preferred, there is a problem. To raise a confirmed theory sentence, the proposition, of that kind to the level of an invariance *is tantamount to saying that something preferred is unattainable.* This is vastly different from saying that it was never attained in the past…
>
> This becomes more dramatic as soon as different groups in society hold different values, and "science" excludes what is valued by one, and not what is valued by another. In that case, "science" is obviously on the side of the one and not of the other, pronouncing as factual what one group wants and as non-factual ... what is valued by the other group. (Galtung, 1977, pp. 73-74.)

Galtung (1977, p. 73) perceives a prediction as a specification of an invariance, and an invariance as a generalization involving the future. Invariance seeking research attempts to find general laws on which technologies can be built. Finding invariances within the realm of natural sciences has stimulated considerable technical development. These kinds of research have mainly been performed by researchers adhering to LE schools. When research in social and cultural sciences finds apparent invariances Galtung (1977, p. 73) considers them as ideological statements. Apparent invariances found in social studies could stimulate further investigations in order to envision possible future worlds in which they are broken. Such studies focus on hidden ideologies and question them. Researchers working dialectically within a school of HD perceive invariance breaking activities as an option.

Galtung (1977, p.72) briefly states, there do not exist any laws in social science. What he seems to refer to are grand theories under which to subsume individual cases in order to explain them.

This ends my presentation of two different scientific traditions. The next section presents an alternative way to conceive of informing science.

Generalizing how to conceive of Informing Science

A Suggested Generalization

As noted in the introduction, Cohen (2009) proposes that:

"The fields that comprise the transdiscipline of Informing Science

- provide their ***clientele*** with ***information***
- in a ***form***, ***format***, and ***schedule***
- that ***maximizes its effectiveness***. "

In light of the previous discussion of scientific traditions and for a number of reasons that will be given below, I propose generalizing that description to the following:

The fields that comprise the transdiscipline of informing science

- ***orient*** and ***reorient*** their ***clientele*** by
- providing ***data*** and ***meta-data***
- in ***forms***, ***formats***, and ***schedules***
- that ***enable them to act ever more adequately***.

In this section, I explain why it makes sense to employ this broader definition. Some of the changes are easy to explain. For example, in my formulation I intentionally use "forms, formats, and schedules". The singular form might make readers believe that only one particular form, etc., suited for computerization, is implied. Similarly, the criterion of "maximizing effectiveness of informing" risks hiding important interpersonal processes behind a veil of "objectivity", as is so often done in mathematical economics. By using the term "adequately", I intend open up research into areas such as "Who are those to judge what constitutes a way to act more adequately?" This will involve negotiating: Who are the stakeholders? How can these reach an acceptable agreement on the issue? This opens up questions about unequal power distribution between different stakeholders.

Most of the changes I propose, however, warrant further explanation. For example, in the section "Clients perceived as whole human beings" I explain the terms "orient and reorient". Informing oneself or others are human activities. They must not be separated from other forms of human ways of acting. The clientele I assume to be autonomous and responsible actors capable of reflecting critically.

Details of a Broader Framework

The alternative framework for informing science in Figure 1 distinguished three domains of observation – one of human living/

acting, and one of reflecting, and one of creating new resources. In the following subsections I shall discuss each of these in turn.

The domain of human living and acting

Figure 2 presents the domain of human living and acting. People live and act in the two other domains too. This domain, however, I perceive as the one of which practitioners, rather than academic teachers and researchers, have most experience.

Figure 2 presents everyday living and acting as recurrent sequences of observe-orient-decide-act. This is a sequence adapted from Whitaker (2007, pp. 83-88) and originally presented as the OODA Loop of Col. John R. Boyd (1987). People don't think of their lives and work in these terms. However, when the way they act does not turn out as expected, it helps to reflect in these terms. As Whitaker (2007, p. 86) reports unexpected events in practice offer analysts and designers a good basis for their work: "The best clues for constructive interventions are derived not from what 'works', but from what doesn't. These shortcomings and pitfalls are typically evident only to the people who must confront them on a daily basis." Whitaker (2007, p. 87) in this context gives more practical advice to analysts and designers:

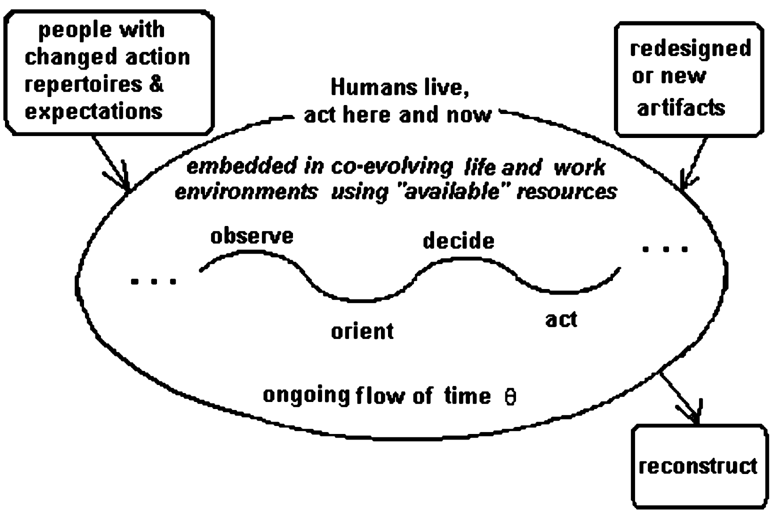

Figure 2: People living and acting in the flow of time.

"Because my modeling and analysis approach emphasizes the work process path, discerning the actual course of work activity is critical to success. A particularly rich source of clues lies in any personally- or locally-created work aids (check lists, 'cheat sheets', and the like) the workers have generated to support their own work praxis. Where such aids have been developed, one can usually assume the work activity entails complexities that must be addressed or accommodated in the eventual IS design. Such homegrown aids can provide direct evidence of gaps or deficiencies in current work support, and in some cases I've found them to be directly convertible into well-accepted IT features and artifacts. In any case, a robust description of actual praxis gives the designer an inventory of steps, terms, and / or actions that should be reflected in the eventual design."

The environments and the ongoing life and action of people are in Figure 2 presented as co-evolving. This emphasizes that one must remain aware of the fact that environments are changing too.

The domain of reflecting

Figure 3 illustrates the domain of reflecting. As previously mentioned, Schutz (1967, pp. 45-47 and p. 57) has presented good reasons that reflecting on an event comes after the fact. Similarly projects for creating new resources precede work to realize them.

In this domain too I present people and their environments as co-evolving. By presenting the environments as "intellectual" I differentiate them from the more "concrete" environments in the domain shown in Figure 2.

The domain in Figure 3 feeds ideas to the domain of creating new resources. However, creating new resources entails processes that, to be realized, will use resources. Some of the new resources created might, when taken into use, free earlier used resources.

Others, however, might at least initially demand more resources when put in use. Some of the dynamic complexity involved has been addressed by Senge (1990). Conflicts regarding means for creating new resources may arise. Who are those balancing between the two lines of creating new resources?

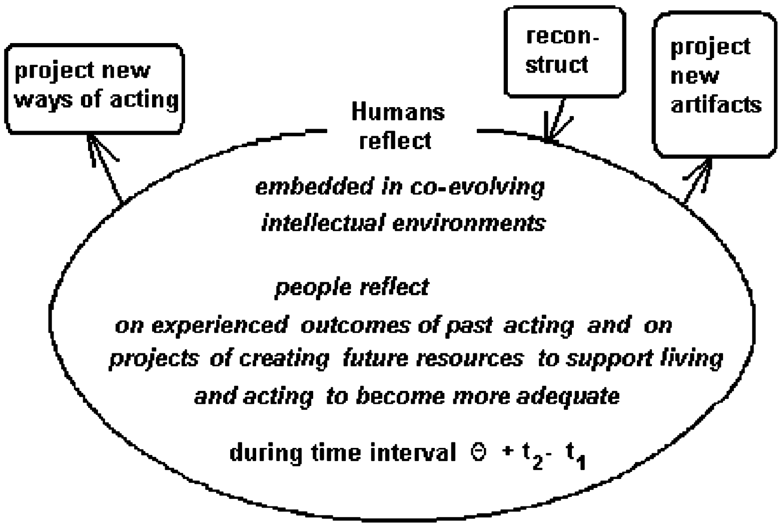

Figure 3: People reflecting on experience and future possibilities.

The domain of creating new resources

Figure 4 illustrates the domain of creating new resources. This domain is comprised of people learning and unlearning action repertoires *and* designing or redesigning artifacts. There exist several reasons for distinguishing these processes. Unlearning old ways of acting, particularly in situations under stress, is generally a hard task. Acquiring new action repertoires entails the use of already existing artifacts. Most people, who later will use a new artifact, never took part in developing it. For off the shelf software this certainly is the case.

Learning will have to take place during actual use of an artifact. Stated thus, this might seem trivial. In the history of artifacts times of co-evolution of a type of artifact and of people using them can be traced. During these times people's way of acting and the artifacts have mutually influenced each other. How documents have been handled from the time human beings invented writing to today's electronic data bases furnishes just one example.

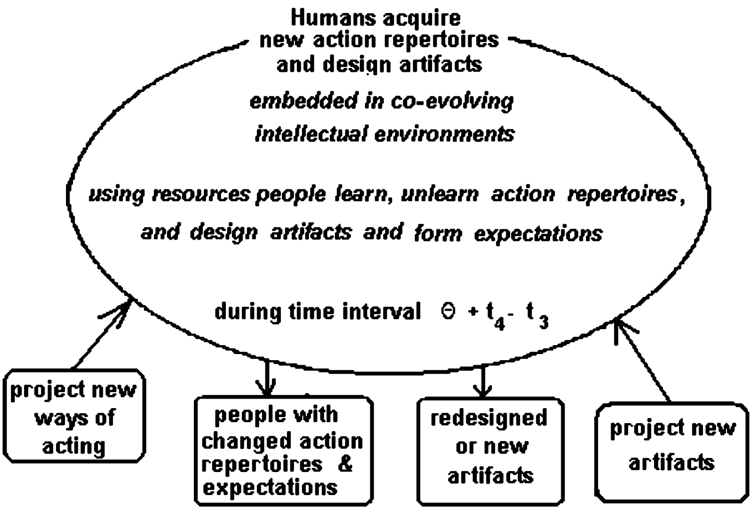

Figure 4: Acquiring new action repertoires and designing artifacts.

Comparing the two Descriptions of Informing Science

In this section I will compare the two ways of circumscribing informing science and their frameworks. So far I have presented three important differences as shown in Table 2.

By roles I refer to people strictly acting according to what is expected of them by others and themselves in particular situations. All people take on many roles during their lives. However, to act as whole human beings, they will, even while acting in some role, sometimes enact it outside of what the role prescribes as proper action. Implicit assumptions make a text open to incompatible interpretations. This is my reason for stressing what explicitly is assumed. However, for practical reasons the set of explicitly stated assumptions always has to remain limited.

To perceive people as whole human beings entails some more detailed assumptions. My order of presentation should not be taken as an order of their importance. First I will discuss some assumptions, which are connected to my stress on perceiving people as whole human beings.

Table 2. Comparing two informing science descriptions.

Cohen's (2009) framework	A broader framework
Makes only linear chains of determination explicit.	Explicitly introduces circular chains of determination.
Explicitly only introduces roles people play.	Explicitly introduces people as whole human beings.
Does not explicitly introduce time and time delays.	Explicitly introduces time and time delays.

Some Assumptions to focus on Whole Human Beings

Western philosophies have since Descartes uphold a distinction between body and mind. As argued in Lackoff and Johnson (1999), based on empirical evidence, the Cartesian person, with a mind wholly separate from the body, does not exist.

Lackoff and Johnson, based on studies of metaphors used in everyday language and of color vision, conclude:

- The human mind is inherently embodied.
- Thought is mostly unconscious.
- Abstract concepts are largely metaphorical.

Lackoff and Johnson (1999, p. 3) present these as: "… three major findings of cognitive science." Here a distinction has to be introduced between the second generation of cognitive science, which Lackoff and Johnson refer to, and the first generation of cognitive science. Varela, Thompson, and Eleanor Rosch (1991) also present much evidence that minds are embodied.

Lakoff and Johnson (1999, p. 17) describe their findings that minds are inherently embodied in the following way: "Cognitive science provides a new and important take on an age-old philosophical problem, the problem of what is real and how we can know it, if we can know it. Our sense of what is real begins with and depends crucially upon our bodies, especially on our sensimotor apparatus, which enables us to perceive, move, and manipulate, and the detailed structures of our brains, which have been shaped by both evolution and experience."

The above findings by Lackoff and Johnson (1999) help focusing on whole human beings. This is my reason to suggest they are included as assumptions in a generalized framework for informing science.

Cognitivism or first generation cognitive science	**Second generation cognitive science**
First generation cognitive science evolved in the 1950s and 1960s, centering on ideas about symbolic computation… It accepted without question the prevailing view that reason was disembodied and literal — as in formal logic or the manipulation of a system of signs. (Lakoff and Johnson,. 1999, p. 75.)	By the mid- to late 1970s, a body of empirical research began to emerge that called into question each of these tenets of Anglo-American "cognitivism." … a competing view of cognitive science developed … in the face of two kinds of evidence: (1) a strong dependence of concepts and reasons upon the body and (2) the centrality to conceptualization and reason of imaginative processes, especially metaphor, imagery, metonymy, prototypes, … (Lakoff and Johnson, 1999, p. 77.)

Clients perceived as Whole Human Beings

In Cohen (1999, 2009) the concept of 'clientele' plays an important role. In Chapter 3, Gill and Bhattacherjee discuss the role of the clients in the context of informing science. When they use the concept 'clientele' they refer to clients of different kinds. I will use the concepts 'clientele' and 'client' in a way similar to Gill and Bhattacherjee's. My assumption that senders and clients should be studied as whole human beings also entails their heterogeneity.

The concept of 'client', as well as those of 'customer' and 'patient', generally connotes a perspective of some specific service given to an individual by somebody else. This misses perceiving individuals as whole persons in their own right. An example is the habit of information technology specialists to talk about "users". This focuses on a narrow aspect of the persons referred to. They should be referred to as whole human beings or as professionals in their own right.

In a framework assuming circular chains of determination I suggest using the terms “orienter” and “orientee” instead of Cohen's (2009) "informer" and "client". These I borrow from Maturana and Varela (1980, pp. 28-32). The same person or group of persons generally shifts between being an orientee or an orienter. My reason for preferring these two terms will be given in the next subsection.

Orienter	**Orientee**
A person sending messages, who intends to orient receivers by them, but does not control the interpretations of the receivers.	A person receiving messages, who interprets these independently of what their senders intend them to mean. This is generally not assumed of a receiver according to classic information theory.

An excursion into Piaget's theory of learning

As discussed in the section "Informing versus information systems" people interpret data in messages applying their pre-knowledge. This way an informee can become informed. However, this misses the fact that a person's pre-knowledge evolves over time. As von Glasersfeld (1995, pp. 62-63) explains Piaget has developed a model integrating interpretation based on pre-knowledge and acquiring new knowledge.

> Both assimilation and accommodation are key terms in Piaget's theory, and they are also among the most misunderstood…
>
> … Using Piaget's definition, one can say: The cognitive organism perceives (assimilates) only what it can fit into the structures it already has. This, of course, is a description from the observer's point of view. It has actually the important implication that when an organism assimilates, it remains unaware of, or disregards, whatever does not fit into the conceptual structures it possesses.
>
> Because no experiential situation in the life of an organism will be *exactly* the same as another, it is clear that in many cases it is advantageous (and therefore adaptive) to disregard differences. The peculiarity here … is that the adaptation seems to go in the

> opposite direction of the usual: perception modifies what is perceived in order to fit it into the organism's structures …
>
> In short, assimilation always reduces new experiences to already existing sensimotor or conceptual structures, and this inevitably raises the question why and how learning should ever take place…

To include learning Piaget has introduced a scheme of actions or operations. How he does this von Glasersfeld (1995, pp. 65-66) presents in the following way:

> " This new perspective can be indicated by a change of terminology, and I have come to specify the three parts of schemes as follows:
>
> 1. Recognition of a certain situation;
> 2. a specific activity associated with that situation; and
> 3. the expectation that the activity produces a certain previously experienced result.
>
> …
>
> The 'recognition' in part 1 is always the result of assimilation.
>
> …
>
> The activity, part 2, then produces a result which the organism will attempt to assimilate to his expectation part 3. If the organism is unable to do this, there will be a perturbation … if the initial situation 1 is still retrievable, it may now be reviewed … This review may reveal characteristics that were disregarded by assimilation. If the unexpected outcome … was disappointing, one or more of the newly noticed characteristics may effect a change in the recognition pattern and thus in the conditions that will trigger the activity in the future. Alternatively, if the unexpected outcome was pleasant or interesting, a new recognition pattern may be formed to include the new characteristic, and this will constitute a new scheme. In both cases there would be an act of learning and we would speak of an 'accommodation'..."

Informees inform themselves or become informed. Talking about orientees it makes sense to distinguish between orienting themselves and reorienting themselves. Similarly one could say that an orienter intends to orient or reorient an orientee. When oriented by a message a person assimilates it according to her current pre-knowledge. When reoriented by a message a person accommodates it. This means that she also revises her pre-knowledge – i.e., that she learns.

End of clients as whole human beings

In Chapter 3, Gill and Bhattacherjee discuss the fact that clients both may be individuals or groups of people. How to integrate individual and group levels constitutes a recurrent problem in social sciences. Bateson (1980) has offered one way to resolve this problem by introducing a generalized concept of mind.

Bateson on Minds

Bateson's way of generalizing minds is based on his key concept of a 'difference'. "Of all these examples, the simplest but most profound is the fact that it takes at least two somethings to create a difference. To produce news of difference, i.e., *information*, there must be two entities (real or imagined) such that the difference between them can be immanent in their mutual relationship …" (Bateson, 1980, p. 78.)

Bateson's construct of 'difference' is the foundation for his explanation of his concept of 'mind'. At the beginning of a chapter on "Criteria of Mental Processes" Bateson (1980) lists six criteria for what he would call a mind:

- A mind is an aggregate of interacting parts or components.
- The interaction between parts of mind is triggered by difference, and difference is a nonsubstantial phenomenon not located in space or time;
- Mental process requires collateral energy.
- Mental process requires circular (or more complex) chains of determination.
- 5. In mental process, the effects of difference are to be regarded as transforms (i.e., coded versions) of events which preceded them. The rules of such transformation must be comparatively stable (i.e., more stable than the content) but are themselves subject to transformation.

- 6. The description and classification of these processes of transformation disclose a hierarchy of logical types immanent in the phenomena.

I shall argue that the phenomena which we call *thought, evolution, ecology, life, learning,* and the like occur only in systems that satisfy these criteria. (Bateson, 1980, pp. 101-102.)

Bateson (1980, p. 231) declares the Cartesian dualism separating 'mind' and 'matter' as obsolete.

As one of his criteria for minds Bateson mentions circular chains of determination. These I have called "closed cause-effect chains". Bateson also argued that to understand processes of learning it would help to look for such chains. To learn means to know more, individually or collectively. To inform oneself or others implies an intention to make people more knowledgeable. By her autonomy of interpretation an orientee can safeguard herself against not well supported messages and misinformation.

To the set of assumptions for informing science I want to add:

- Descriptions of mental processes have to acknowledge a hierarchy of logical types inherent in the phenomena.

For instance, individual and collective learning have to be described and analyzed as phenomena on different levels of logical type. Argyris (1990, pp. 88-89) has introduced a similar distinction to show on which level of abstraction a description is made. He calls it "a ladder of inference". It comprises four rungs: (1) relatively directly observable data, such as conversations; (2) culturally understood meanings; (3) meanings imposed by us; (4) the theories we use to create the meanings on rung 3.

To a large extent people interact by communicating. Assumptions about human communication will follow next.

Some Assumptions about Human Communication

Recall that I assumed clients to be autonomous and responsible actors capable to reflect critically. This contradicts Shannon's assumption that the decoder offers an exactly inverse function of the encoder. In pragmatics of human communication this generally will not be the case. Hence, sender and receiver may interpret the same data differently.

Pragmatics

Semiotics, the study of signs and languages, distinguishes often three levels of abstraction. *Pragmatics* studies the way languages are used in practice. *Semantics* abstracts from usage and focuses only on the relations between signs of a language and their meaning. *Syntax* further abstracts and considers signs aside from what they mean.

In my suggested description of informing science I have substituted the words "data and meta-data" for "information". *In order to inform data have to be interpreted by somebody.* Langefors (1966, p. 197) stressed the importance of distinguishing between the concepts of 'data' and 'information'. An easier to read presentation of this distinction was given in Langefors (1995, chapter 9). Checkland and Holwell, moreover, have underlined the fact that data are not given but selected.

Data or capta

The term "data" is often used in everyday language as a synonym of "information". In the context of information systems research the term "data" should be delimited to denote "means for presenting information" or "digital or alphabetic symbols presenting part of a message". In order to inform data need to be interpreted by an observer, who relates them to his pre-knowledge. (Langefors (1995, pp. 144-148).)

Sometimes the term "data" is used to refer to what in a court trial would be called "not contested evidence". The fact that data are not given but somehow selected has been stressed by Checkland and Holwell (1998, pp. 86 – 92). To indicate this they suggest using the term "capta".

In other contexts, for instance, when Galtung (1977) discusses "data sentences" versus "value sentences" the term "data" refers to descriptions of observations.

By not using the noun "information" the misleading association that "information" could be packaged and shipped like a commodity is avoided. This misconception was criticized by the American linguist

Reddy (1979) under the name of "The conduit metaphor". However, as Reddy has written in Reddyworks (2009): "Early on … I established that English has its own, somewhat misleading, "folk theory" of how human communication works. … In recent years, references for "conduit metaphor" in Google have ballooned … What amazes me is that many of these references seem to feel I said the opposite of what I said!!"

The conduit metaphor for communication

The central core of this metaphor is based on the following assumptions: "(1) language functions like a conduit, transferring thoughts bodily from one person to another; (2) in writing and speaking, people insert their thoughts and feelings in the words; (3) words accomplish the transfer … to others; and (4) in listening or reading, people extract the thoughts and feelings once again from the words." (Reddy, 1979, p. 290.)

Lackoff and Johnson (1980, p. 232) write about the risks of basing *theories of human communication on the conduit metaphor:*

> " Communication theories based on the CONDUIT metaphor turn from the pathetic to the evil when they are applied indiscriminately on a large scale, say, in government surveillance or computerized files. There, what is most crucial for real understanding is almost never included, and it is assumed that the words in the file have meaning in themselves—disembodied, objective, understandable meaning. When a society lives by the CONDUIT metaphor on a large scale, misunderstanding, persecution, and much worse are the likely products."

Based on the presentation in this section a generalized informing science framework also should assume:

- Data or capta in themselves do not inform or orient human beings.
- Human communication will be misunderstood if it is believed to occur according to the conduit metaphor.

In human communication people mainly use everyday language and common sense. These differ considerably from using formal languages in computer mediated interaction and in arriving at inferences by inference engines. (See the subsection "Human use of calculi".) The next section as a whole will address human communication.

Assumptions about language use and calculi

Both in creating and in using informing systems we, as human beings, predominantly use everyday language. There are significant difficulties in analyzing and changing habits of language use. From childhood we have become socialized to communicate by talking and writing. Later we have further been socialized into different subgroups. These often have developed their sociolects. As human beings we seldom consciously reflect about our everyday language use. When we draw conclusions we do not apply formal logic to arrive at them.

My informing science framework I have suggested to assume that human thinking, including preparing to act, mostly occurs on unconscious levels. The framework hence cannot ignore informal communication.

Pragmatics of human communication. Following Watzlawick, Beavin, and Jackson (1967) I interpret human communication in the broad sense that people communicate by all kinds of behavior. In a section on "The Impossibility of Not Communicating" they write:

> " First of all, there is a property of behavior that could hardly be more basic and is, therefore, often overlooked: behavior has no opposite. In other words, there is no such thing as nonbehavior or, to put it even more simply: one cannot *not* behave. …" (p. 48).

Moreover, according to Watzlawick, Beavin, and Jackson (1967) there exists both a content and a relationship level of communication:

> "... in the foregoing it was suggested that any communication implies a commitment and thereby defines the relationship. This is another way of saying that a communication not only conveys information, but that at the same time it imposes behavior. Following Bateson ... these two operations have come to be known as the "report" and the "command" aspects, respectively, of any communication. ...
>
> The report aspect of a message conveys information and is, therefore, synonymous in human communication with the

> *content* of the message. … The command aspect on the other hand, refers to what sort of a message it is to be taken as, and, therefore, ultimately to the *relationship* between the communicants. ..." (pp. 51-52)

Ideas similar to the command aspect mentioned above have been developed by Austin (1962) on how language use can result in that things are done. Austin's ideas have been developed into speech act theory. This theory has later developed to describe speech acts as regularly formed. In this form speech acts do not contribute any aspects on informal communication and I will not discuss them further.

Following this subsection I suggest adding the assumption:

- In studying informing systems both linguistic and non-linguistic human actions have to be observed.

In a sense the focus on task performance in Cohen (1999, 2009) indicates a similar assumption.

How people draw inferences and how computers, and particularly inference engines, are programmed to do so differs. I now turn to this issue.

Human use of calculi. Computerized parts of informing systems can do more than transmit linguistic and other symbolic expressions over space and time. They can also transform some expressions into new ones. For example, they can be programmed to follow ordinary or matrix algebra. They can also be programmed to draw logical conclusions, generally according to first order predicate logic. This, too, is a form of calculus.

To perform calculation as computers do, entirely based on syntactic form, puts severe restrictions on the language used, however. The philosopher Wittgenstein reflected deeply on different language forms. In Wittgenstein (1974) he devised a language suitable for deductions by logical calculation. This becomes clear when Wittgenstein (1974) in his statement 3.33 writes:

> "In logical syntax the meaning of a sign should never play a rôle. It must be possible to establish logical syntax without mentioning the *meaning* of a sign: *only* the description of expressions may be presupposed."

Here the description of an expression refers to the description of its form. By "logical syntax" Wittgenstein refers to rules of transformation of a calculus. In his later writings, for instance, in Wittgenstein (1958, 1963), he stresses that language as used in everyday life does not resemble such a calculus:

> "... For remember that we in general don't use language according to strict rules — it hasn't been taught us by means of strict rules, either. *We*, in our discussions on the other hand, constantly compare language with a calculus proceeding according to strict rules.
>
> This is a very one-sided way of looking at language. In practice we very rarely use language as such a calculus. For not only do we not think of the rules of usage — of definitions, etc. — while using language, but when we are asked to give such rules, in most cases we aren't able to do so. We are unable clearly to circumscribe the concepts we use; not because we don't know their real definition, but because there is no real 'definition' to them. To suppose there *must* be would be like supposing that whenever children play with a ball they play a game according to strict rules." (Wittgenstein, 1958, p. 25)

Calculations performed by inference engines are based on categories formed according to set-theory. This means that every member of a class (category) shares the attributes defining class membership. This is according to findings by Lakoff and Johnson (1999, pp. 17-20) not the way people generally use in their reasoning. Instead of set-theory based categories they use *prototype categories*. As Lakoff and Johnson (1999, p. 19) explain:

> " … Categorization is thus not a purely intellectual matter, occurring after the fact of experience. Rather the formation and use of categories is the stuff of experience… In short, prototype-based reasoning constitutes a large proportion of the actual reasoning we do…"

This subsection leads to adding the following assumptions:

- The way human beings draw inferences cannot and should not always be forced into patterns of strict rules.
- Human beings generally reason in prototype categories.

The assumption that everyday language does not follow strict, formal rules Wittgenstein has developed by introducing his 'language games'. In the next subsection I will present this concept.

Language games. As a metaphor for language use in practical life Wittgenstein (1963) introduces what he calls "language games". By means of these he puts language use into the stream of everyday life situations. Blair (2006) explains Wittgenstein's metaphor of language games thus:

> " The *language-game* is one of the most important components of Wittgenstein's philosophy of language. Wittgenstein resists … giving a rigorous definition of it, but that does not mean that it is not a rigorous notion. As usual, we must see its rigor in the examples Wittgenstein gives us. The problem that Wittgenstein faced was how to reconcile the need in language for a predictable structure that determines how words in language go together, with the simultaneous need for flexibility in usage…" (p. 80)

Blair (2006) then goes on to make a list of the important aspects of language games. He adds that this list is not meant to be exhaustive or final. Nor is it necessary that all games exhibit all these aspects.

1. *A predictable structure*: Usually codified as a set of rules and may be written down in some sports, like baseball or football, or may be proposed informally by casual players of a game...
2. *A point or a goal*: This provides a focus for the intentions of the "players", although not all games, as Wittgenstein rightly points out, have a goal ...
3. *Flexibility of performance*: There is a wide latitude in terms of what kind of performance is permitted within the boundaries of the game's structure ...
4. *The need for training and practice*: In order to "play" the game, one needs to be taught how to play. Some of this teaching may take the form of explanation, but most of it takes the form of being coached …
5. *Performance is not necessarily accompanied by conscious mental processes*: Many highly skilled athletes claim that they have little conscious thought during their performance ...

6. *Games are imbedded in, and influenced by the larger context of human activities.* This provides a way of instilling extraordinary complexity into a game without having to codify all of the complexity ...

7. *Games help individuals build and refine their social and interpersonal skills,* such as, the ability to follow rules reliably, the ability to make and interpret rules, the ability to coordinate one's actions with others, etc.

8. *Games take place over time,* ... (pp. 80-84)

I have included this lengthy excerpt from Blair (2006) for two purposes. It sheds light upon Wittgenstein's concept of 'language games'. It also suggests a potentially useful similar concept of '*work-task-games*'. Workers have difficulties in describing their work tasks precisely to designers of computer support. Moreover, they need to learn and acquire skills in the modified work-task-game to play, once some new computer support has become implemented. It falls outside the scope of this chapter to develop this suggestion further.

The very idea of language games supports the inseparability of language use and human action, including non-linguistic action. Point 5 states an assumption also arrived at by second generation cognitive scientists. Human thinking and acting mostly occurs on unconscious levels. Point 10 indicates that a diachronic perspective, advocated in HD research traditions, sometimes might help.

Assumptions about rationality of whole human beings

An example from pedagogy. In a world of conflicting interests it seems difficult to agree upon indicators of effectiveness. This issue largely falls outside the scope of this chapter. However, I will illustrate the most salient points by reference to a relevant discussion comparing rationalities.

In the late 1970s, Dunne (1993, p. 1), and his colleagues were "formally introduced to a new model of teaching that promised ... spectacular improvements in the quality of our students' teaching if only they (and we as their mentors) would use it as a blueprint in planning and conducting lessons". The model was called the *objectives model* and opened the road to *efficiency* in teaching. Dunne and fellow teachers felt that the objectives model ran up against their experience in classrooms.

This triggered him to closely examine representative texts on the model. This examination brought him to study a larger philosophical context.

Later in his introduction Dunne summarizes his critical views of the objectives model in pedagogy:

> "... Nor is there any sense that ... something might be at work in the pedagogic situation which cannot simply be made the object of analysis but rather must be lived through — a kind of subsoil which nourishes the fruits of explicit purposes but which is not itself a fruit. It is as if action can be resolved into analysis — that the problems of the *first-person agent* can be solved from the perspective of the *third-person analyst.* As a form of action, then, teaching is no longer seen as embedded in particular contexts or within cultural, linguistic, religious, or political traditions which may be at work in all kinds of tacit and nuanced ways in teachers and pupils as persons…" (p. 5). (Emphases by the current author.)

Dunne's illustrative background is taken from teaching, one form of informing people. However, this quotation to me seems, mutatis mutandis (i.e., with necessary changes being made), applicable to other relations. For instance, there are parallels to the relations that exist between system analysts and workers. The analysts remain third-person observers. The workers, as first-person agents, have to make sense, in particular situations, of data from data processing systems.

Dunne (1993, p. 5-6) describes the logic behind the objectives model as an *instrumentalist* one. Its adherents saw means in themselves as value neutral and hence substitutable in principle by any other means. All questions of value became located at the level of (or translated into) ends. Value discussions, however, became attenuated by demanding ends which had become cast into discrete, observable behavior. To evaluate atomistic objectives requires study of their effects aggregated over time. The adherents of the objective model did not include this kind of evaluation on a higher level in the techniques they recommended. Dunne admits that instrumental reason constitutes *a logic*. But he does not accept it as a universal standard that should determine all rational action:

> "... the problem confronting me was to show that this standard constituted *a* logic or *a* form of rationality — one which has its

> own biases, limitations, and (when these limitations were not acknowledged) distortions — and that it did not, therefore, define exclusively what is meant by 'logical' or coincide with rationality *as such.* " (pp. 7-8).

The supplementary form of rationality Dunne offers I roughly characterize as a historically, linguistically, and culturally based rationality exhibited by people in their everyday action. Dunne states that his critical analysis of forms of rationality applies not only to pedagogy but to other fields too. He mentions political activity, organizational and management practices, psychotherapy, and community development (p. 8). All these fields involve people informing themselves and others. The rationality of instrumental reason corresponds to the view on rationality within LE traditions. Dunne's (1993) alternative rationalities correspond to views within HD traditions.

An example from management. In a paper Kawalek (2007) reports a case of problems entailed in transplanting an Enterprise Resource Planning (ERP) program package from one enterprise culture to a different one. The consultants called in by management to implement the new package applied a narrow focus on the task of implementation.

> "… the ERP implementation team … had been too focused on a simplistic view of the organisational processes (and the 'rationality' in them), and had assumed that their key purpose was to attempt to optimize a given (rather ill-defined) process, by attempting to 'mechanise' it, which was only sometimes appropriate. The e-learning platform, recorded some of these discussions, *"… they took their experience of another organisation, and imposed it on us …", "we don't work as machines in this company…", "… they never really tried to understand how we do things 'round here…", "… a lot of things changed … but nothing changed …"* " Kawalek (2007, p.114).

This example also illustrates the potential usefulness of the distinction introduced in the section "Establishing informing systems" above. The managers should have been aware of the difference between implementing a program package and reestablishing an informing system. Only by doing this could they have given their resource planning staff a position equal to that of the consultants in the transition process.

Moreover, this example should not be looked upon as a situation seldom encountered. Hassan (2006, p. 248) points out that adherents of instrumental theories, which hold that science creates neutral technologies, will believe that:

> "… Technology is indifferent to politics and social issues, to the objectives of its users, and its transfer is only limited by costs. It also implies that research relating to technology need only to be rationally verifiable; thus, what works in one organization or society can be expected to work in another…"

An assumption to add. The logic behind rationality according to instrumental reason presupposes human reasoning and action to be entirely conscious. Dunne (1993) gave evidence there exist other rationalities than instrumental ones.

Dunne's discussion of instrumental reason constitutes *a logic* that supports adding the following assumption to the broader framework:

- Reasoning of human beings can be rational even if it does not follow the logic of instrumental reason.

As an illustation, computer support for production planning, inventory control, etc. has been offered assuming it cannot but improve effectiveness. This has not always turned out to be valid. The reason generally was a primary focus on implementing a new technology often entailing new models of how to reach decisions. Too little attention was given to the complex and variable contexts of situations to handle. The clients did not perceive that the computer support helped them to act more effectively. Cohen's original proposal to maximize effectiveness belongs to the realm of instrumental reason. Hence, the last assumption mentioned above cannot be implied in his framework.

The just mentioned distinction between *first-person* and *third-person perspectives* is important enough to deserve the following subsection.

Understanding and perspectives

To acknowledge the difference between *first- and third-person perspectives* might improve mutual understanding and communication between the two parties. Advocates of participatory design (PD), as for instance, Ehn (1988) based the notion of PD on this very point.

First person perspective	**Third person perspective**
The point of view or vantage of a given observer/actor herself or himself.	The point of view or vantage of an observer when she/he observes another person.

Clients perceive their tasks from a first-person perspective. This they have acquired from experience in interaction with other human beings, artifacts, and material in their environment. Still, in the final analysis a first-person perspective remains subjective. Unfortunately, system analysts and designers who develop computer support for some work task typically only acquire a third-person perspective of the work task. This is also valid for the managers, who employ the system analysts and designers.

Whitaker (2007, pp. 65-66), based on more than 15 years of practical experience of developing computer support, testifies to the importance of the distinction under discussion:

> "Both phenomenology and hermeneutics focus on the subjectivity of a given person or actor. Phrased another way, these orientations frame their inquiry with regard to some- one's 'first person perspective'… The works of both Husserl and Heidegger illustrate the extreme of abstraction in their treatments of what can be present to experience (Husserl) and the actor's essential mode of being (Heidegger). Insightful though they are in educating IS professionals on human cognition and activity, neither offers much that can be directly incorporated into practice. Similarly, hermeneutics elucidates interpretation and interpretability without providing specific tools or methods for leveraging the understanding one can obtain from its study.
>
> In large part, this apparent deficiency derives from these fields' foci. Both phenomenology and hermeneutics emphasize processes and elements intrinsic to the given actor – e.g., what she perceives, the manner in which she thinks, or her capacity for interpretation. This imposes a methodological problem, because an analyst cannot directly inspect the target actor's mind or thoughts. The analyst must address the target actor from a third-person perspective (3PP) from which any characterization

> of that actor's 1PP … is at best an allusion and at worst an illusion."

A closely related difference in perspectives is the one discussed by Suchman (1987) between devising plans and acting in a concrete situation. In planning a planner cannot but take a third-person perspective in relation to an actor in a concrete situation. This remains valid even if the two happen to be the same person at different times. An actor while acting applies her first-person perspective. To recognize and acknowledge this difference induces an inversion of traditional social theory. Eriksén (1998, pp. 186-187) describes the relevance of this for design of work in organizations and information technology in the following way:

Hermeneutics	**Phenomenology**
Hermeneutics may be described as the development and study of theories of the interpretation and understanding of texts. The concept of 'text' is here also extended beyond ***written*** documents to any objects subject to interpretation. Somewhat simplified hermeneutics addresses issues of interpretation and interpretable phenomena.	Phenomenology is the study of structures of consciousness as experienced from the first - person perspective. It generally focuses on everyday life experience. The central structure of an experience is its intentionality, its being directed toward something. Somewhat simplified phenomenology focuses attention on perceived everyday life experience

> " In her book *Plans and situated actions*, Lucy Suchman shows how Mead's and Blumer's concepts of human acts, along with recent developments within anthropology and sociology — especially ethnomethodology — challenge traditional assumptions about purposeful action and shared understanding. Such traditional assumptions, based on traditional social theory, still underlie much of the design of work in organizations and information technology…
>
> One of the main consequences of this inversion of traditional social theory is, that it makes very clear the importance of

> studying human action and interaction *in situ*, looking not for a structure that is invariant across situations, but for how the significance of actions and artifacts is established and conveyed in specific, unique situations. It is through our everyday social practices that we make sense of the world… "

This inverted look on social theory is compatible with the assumptions mentioned above grounded in second generation cognitive science. The reasons given above to distinguish between first-person and third-person perspectives motivate the following assumption:

- When human actors observe and act this can be directly perceived from a third-person perspective. The orient and decide phases of action, however, are directly accessible only from a first-person perspective.

This assumption is particularly important when circumscribing the interpretive problems of designers. These have been comprehensively described in Whitaker (2007, pp. 75-86).

Assumptions for a Generalized Informing Science Framework

I have presented a number of assumptions suggested for a generalized framework of informing science. They have been spread out in the text. To help practitioners and researchers to reflect upon them I gather them in this section. Taken out of their earlier contexts I have changed their wording slightly. My proposed framework assumes:

- circular (or more complex) chains of determination;
- three domains of observation, analyses and explanations: a domain of human life and everyday action, a domain of reflection on past experience and future possibilities, and a domain of creating new resources ;
- people to be whole human beings;
- time and time delays to be important;
- informing systems becoming established by the ways people use them, not by the ways external experts implement automatic data processing systems they may entail;
- the human mind to be inherently embodied;
- that thought is mostly unconscious;

- that abstract concepts are largely metaphorical;
- that descriptions of mental processes have to acknowledge a hierarchy of logical types inherent in the phenomena;
- that data or capta in themselves do not inform human beings;
- that human communication will be misunderstood if it is believed to occur according to the conduit metaphor;
- that in studying informing systems both linguistic and non-linguistic human actions have to be observed;
- that the way human beings draw inferences cannot and should not always be forced into patterns of strict rules;
- that human beings generally reason in prototype categories;
- that reasoning of human beings can be rational even if it does not follow the logic of instrumental reason;
- that when human actors observe and act this can be directly perceived from a third-person perspective. The orient and decide phases of action, however, are directly accessible only from a first-person perspective.

This suggested framework must not be taken as final. However, it broadens the areas of practical application of informing science. This it achieves by introducing assumptions, which in a number of cases remove or reduce restrictions on empirical data to gather and analyze - for instance, by accepting more than one kind of rationality, by accepting non-linear cause-effect chains, by accepting unconscious thought, and by exposing the limited applicability of the conduit metaphor. These assumptions therefore reduce constraints on findings in future inquiries.

Conclusions

Informing science has been presented as a transdiscipline. Transdisciplinary researchers and practitioners will have to communicate a lot about their, mostly taken-for-granted, assumptions. Familiarity with metascience could help in this communication.

Informing science studies will need to draw on epistemologies from both LE and HD schools of metascience. References to cognitive science should explicitly state if the first or the second generation of it is implied. Reports on findings should make it explicit whose interests have guided the inquiry. They also should make known to what extent the interests of other stakeholders involved have been used as restrictions. Methods of study should be used in ways which support the interest(s) guiding the given investigation.

During the last ten years using communication and information technologies has increased in people's lives beyond performing work tasks. The value of informing systems has to manifest itself in improved ways of how people live and act. A broader framework for informing science has been proposed in Figures 1 - 4. It can be seen as presenting a meta-model for studying the field of informing science.

A generalized concept of 'informing science' should recognize both informers and clients as whole human beings with embodied minds. To secure the autonomy of clients as interpreters, messages should be looked upon as mediating data or meta-data in need of interpretation.

Both informal and formal channels of communication, supplementing each other, are needed for people to inform themselves and others. Informing and acting cannot fruitfully be separated. Large parts of both these processes occur on unconscious levels.

To bring the practice into focus the concepts of 'informing systems' and 'information systems' should be distinguished. In contrast to information systems, which are implemented, informing systems are established or reestablished.

Designers, analysts, and researchers of informing systems could profit from keeping their role of only having a third-person perspective in mind. They at best to some extent can infer the first-person perspective of the clients they intend to support.

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Chapter 14

Inquiry into Informing Systems: Critical Systemic Thinking in Practice

Peter M. Bednar and Christine Welch

Introduction

Any perceived human activity system is, by definition, also a complex informing system. Human activity systems must continually adapt to their dynamic environments in order to survive. There is therefore critical role for deutero-learning through human sense-making and multiple levels of reflection in bringing this about. In this chapter, the authors suggest a need for an approach based in philosophy as practice, when considering the complexities of informing systems. Our discussion draws upon a variety of reference disciplines that have contributed to developing an epistemology of informing systems discourse. These include systems science, systems thinking and cybernetics (which we explore through the work of Gregory Bateson and C. West Churchman); biological systems (through the work of Maturana and Varela); philosophy (explored through the work of Gerard Radnitzky and Hans-Erik Nissen, as well as Gregory Bateson); and organizational behavior (explored through the work of Borje Langefors, Chris Argyris, and Karl Weick). We conclude by presenting two examples of hermeneutically-informed, phenomenological approaches.

The theme of this chapter is a dialectic we perceive to subsist between meaningful use and reflection upon use in informing systems (using a metaphor of double helix, see Figure 1). We are by no means the first to reflect upon such relationships in a wider context. Vickers (1965), for example, commented upon it in the following way:

"...human history is a two stranded rope; the history of events and the history of ideas develop in intimate relation with each other yet each according to its own logic and its own time scale; and each conditions both its own future and the future of the other." (Vickers, 1965, p.15)

We explore the nature of the symbiosis between experiences people have in using systems to inform themselves (or others) and the evolution of these informing systems. If we follow a metaphor of a two stranded rope, we can see that the coil of one strand influences the coil of the other in an ongoing helix – neither can remain straight without challenging the integrity of the rope. Vickers refers to 'history'. In this paper, we use this term to denote on-going and continuous change of experience, and development of experience (i.e. a process of 'experiencing'), by both individuals and collective groups. The rope metaphor reflects our thinking that human behavior unfolds in a continuous pattern of response to reflection upon experience. As conscious beings, we have no choice but to reflect and thus our consciousness changes from one moment to the next. Börje Langefors highlights the on-going nature of human sense-making processes in his Infological Equation (Langefors, 1966). Our interpretations of perceptions are related to assumptions arising from previous reflections upon our lived experiences. As Langefors expressed it:

"It is natural to say that an "information system" is a system in which essential components are information entities or information processes. Now that we are aware of the distinction between data and information, we know that a set of data cannot be an information entity except when it is combined with requisite pre-knowledge and an interpretation process. Thus to have an information entity, we will have to have, for instance, a person plus some data. The data are not information; they may at best represent information" (Langefors, 1995, p56).

Furthermore,

"The important question of how data or text may inform has been extensively studied under the name "infology". One of the central insights from infology has been that data or texts do not "contain" information (knowledge) but will only, at best, represent the information to those who have the requisite "pre-knowledge" (Langefors, 1995, p28).

The nature of that "pre-knowledge" is not, of course, unproblematic. It is possible for individuals to become entrapped in taken-for-granted assumptions. We will discuss these issues further in a later section of the paper.

Figure 1: Double Helix

Langefors may be regarded as a founding father of the discipline of "information systems". He proposed it as a new subject area to be covered at the third International Conference on Information Processing and Computer Science in New York 1965 (organized by IFIP; The Internaitonal Federation for Information Processing). His proposal was successful, and this was the starting point of the IS academic subject area, followed in 1967 by establishment of the first professorial chairs in this new area. Since then the term "Information System" has become widely used. Unfortunately the concept that Langefors had in mind appears to have been widely misunderstood (Langefors, 1995). He specifically pointed out (1995, p.26) that:

"Information" ought to be something that had to do with informing and this was the real task behind all processing of data" (Langefors, 1995, p52)

For us, the term information system (as described by Langefors) and the term 'informing system' that we might prefer today, are interpreted as having the same meaning – people are an essential feature of such systems. However, this emphasis on "informing" as an interactive process was somewhat lost in the Information Systems community during the two decades that followed Langefors original work. Much work undertaken during this period, influenced by ideas from the field of computer science, tended to describe information as a commodity, created by processing data, which could be transmitted from one individual to another if only the right channels could be designed to support effective transmission. Later work by Cohen and others (e.g., see Cohen, 1999) has since returned our attention to Langefors earlier conception, by setting an agenda for an emerging transdiscipline of "Informing Science". This relationship between traditions in understandings of information systems and, more recently, informing systems, is discussed by Nissen in Chapter 13 of this current work.

A further dimension to the misunderstandings that have characterized work in the field of "Information Systems" has been a confusion over the scope that this term implies. In their eagerness to discuss particular phenomena under investigation, writers on IS often neglect to give their readers a precise definition of the sense in which they understand it. In his 1995 editorial reflections on Langefors earlier work, Bo Dahlbom comments on his thoughts when he first became acquainted with the subject:

"… I did not understand why people in this discipline found it so important to stress, again and again, the distinction between data and information, between data processing system and information system. As a philosopher, I thought that distinction was rather obvious. But while the very idea of an information system as a human organization … may be simple enough in theory, it is extremely difficult to hold on to when you are engaged in software development or discussing what information technology can do. This idea demands a whole new attitude to technology use, and is of course the basis for the new conception of computer systems design introduced by Langefors" (Dahlbom, editor, in Langefors,1995, p.22).

An example of confused thinking is illustrated when looking through the proceedings of the European Conferences on Information Systems from recent years which appear to reveal very few attempts by authors, or even Track Chairs, to define their terms. We can support two very distinct interpretations of the term "Information System" as it is used in the literature (see Figure 2). We have labeled these [IS1] and [IS2] (see Bednar, 1999; Bednar and Welch, 2005). [IS1] refers to individual people, and their use of hardware and software. However, an expanded definition emerges [IS2] once we include their range of inter-individual communicative activities. An organization is comprised of individual people, in interacting, social, communicative networks. Where development work is carried out within assumptions conforming only to [IS1], actors could find their efforts lack synergy. The results may then disappoint the expectations of those who need to use them.

Langefors (1995) points out that interaction and exchange of data is so fundamental to the operation of all the functions of a business organization that it becomes difficult to separate the organization from its Information System conceptually – they are effectively one and the same. Checkland and Holwell (1998, p.111) refer to the concept of an Information System as an instance of a Human Activity System. However, they go on to distinguish the role of serving systems in relation to systems 'to be served'. Information Systems are sometimes categorised as serving systems, and at other times as systems to be served, suggesting that these authors make a distinction similar to our own between [IS1] and [IS2]. Due to a close connection between organizational and informational/communicative issues inherent in [IS2], any initiatives grounded in [IS1] within the same organizational context are likely to 'succeed' only if perspectives grounded in [IS2] are given prior consideration. This is because, when viewed in the context of [IS2], systems analysis and design activity must be seen as a special case of purposeful change, involving individual and collective organizational learning as a processes over time. Support for contextually-relevant individual and collective learning is needed in order to avoid the artificial separation of theory, e.g. standard methodologies, from practice - organizational life as it is lived.

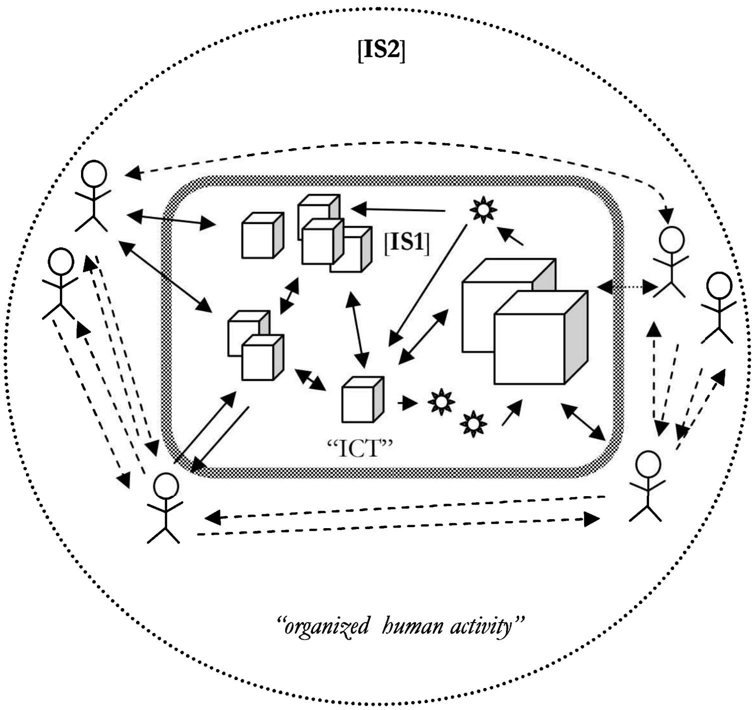

Figure 2: [IS1] vs. [IS2]

Few people would dispute that a dialectic subsists between users' experiences of ICT artifacts and the processes of design and redesign. For example, we may consider the launch of the iPhone by the Apple

Corporation. Undoubtedly, this has been preceded by discussions between designers, and users of cell phones and MP3 music players, to discover which features of these devices might be popular if incorporated into a new artifact. Further testing of devices by prospective users will also have taken place in order to refine design and enhance product development. A great deal of academic debate has taken place in the past around this dialectic relationship. See, for example, discussions by Bijker et al, 1987 and McKay, 1994 in which they debate evidence for technological determinism of social use, as against social shaping of technologies. Langefors reflected on this phenomenon as follows:

"To create new needs seems to imply manipulating people. And, of course, it does… But many needs that have been created by inventors and entrepreneurs in combination are clearly of kinds that people do not want to see disappear… We have, of course, a complex ethical problem here" (Langefors, 1995, p26).

We believe that processes involved in development of 'information systems' must be distinct from those concerned with artifact design. Information (informing) systems may be considered to have a twofold purpose: to support people in informing themselves, and/or to support people in helping others to inform themselves. Research into processes for developing informing systems may be seen as a quest for approaches which combine rigor with appropriate recognition of complexity, and which address meaningfulness of systems from the perspectives of individual participants. We consider that a key to achieving this balance of rigor with relevance lies in creation of an effective learning spiral in which stakeholders (i.e. actors who participate in using informing systems) can engage in reflection within the context of their use. How could this be done? Langefors appears to ask just this question, whilst hinting at a similar metaphor to our own double helix:

"The perspective used here raises questions of how to identify the potential wants of people, their values, on the one hand, and how to discover the new possibilities that are inherent in the developing technology. How does one go about finding answers to questions like "What is desirable?" and "What is possible?"?" (Langefors, 1995, p 26)

Later in this chapter, the authors point to two approaches which support application of hermeneutically-informed, phenomenological inquiry into human activity systems in practice.

The next section of the paper explores the philosophical background and ideas underpinning the discussion. Following this, the authors consider concepts of use, usability and usefulness in relation to the double helix metaphor. A further section then gives two examples of practical application, before we attempt to draw some conclusions. Some readers of our earlier work on this topic (see Bednar and Welch, 2007) have focused on the discussion of usefulness and usability in order to draw a comparison with the Technology Acceptance Model (Davis, et al, 1989). Whilst we are aware of TAM, the philosophical basis of our work is wholly different, and the apparent similarity is both superficial and co-incidental. It is not our purpose to enter into a detailed discussion of this issue, but we have included a small section below.

Systems and Systems for Use

A key aspect of meaningful research in this area, for the authors, is consideration of individual and collective sense-making processes (Dervin, 1983; Weick, 1995). The authors reject a realist approach, which assumes that there is one world 'out there' awaiting individual discovery. Alfred Schutz, writing of the work of Edmund Husserl, puts forward an argument for phenomenological approaches as follows:

'*All empirical sciences refer to the world as pre-given; but they and their instruments are themselves elements of this world. Only a philosophical doubt cast upon the implicit presuppositions of all our habitual thinking – scientific or not – can guarantee the "exactitude" not only of such a philosophical attempt itself but of all the sciences dealing directly or indirectly with our experiences of the world …*' (Wagner, 1970, p.54).

It is this '*philosophical doubt*' that we pursue when we adopt a hermeneutic approach. We recognize that individuals create their own perspectives of '*realities*', through sense-making (see Berger and Luckmann, 1967; Radnitzky, 1970). For us, a kind of critical idealism may be preferred over realism, and thus sharing of '*realities*' is problematic. The way forward is a communicative effort, applying critically-informed systemic thinking, drawing on Gregory Bateson's holistic, hermeneutic approach (Bateson, 1972). The focus is on self-emancipation through systemic meta-reflection from unique individual perspectives of autonomous and self-reflecting systems. Bateson proposes a perspective of human self-awareness and understanding.

When embarking on a design process embedded entirely in an [IS1] paradigm, professionals are attempting to create a system on behalf of '*users*'. They may attempt to consult those '*users*' about their needs, but it is likely that the clients concerned will be disappointed in the extent to which the results are meaningful to *them*. Without inquiry into wider, individual and organizational sense-making processes (i.e. an [IS2] perspective), only a partial view of needs can be formed. Thus, ownership and participation of clients in the inquiry process is vital – they are part of the system to be '*designed*'. In particular, a focus on design of artifacts, in isolation from the individual and organizational contexts within which use will occur, and their associated contextual dependencies, is likely to result in disappointment. At this point, it is worthwhile to reflect also on what we mean when we invoke the term '*user*'. Nissen (2002) points to a difficulty arising through developers' choice of language to use when addressing their clientele. The concept of '*user*', and reference to the needs of '*users*' or '*end-users*' tends to exclude actors within an organization from full participation in, and/or ownership of, the process of design or its outcomes. Clients (i.e. people who perceive a need for a new or modified system to support their work) are unlikely to regard themselves primarily as *users* of IT. They work as managers, surveyors, accountants, chemists, etc. and in their wider life experience, they perceive themselves as parents, family members, friends, sportswomen, etc. Furthermore, as previously mentioned, they are not simply '*consumers*' of information or technologies, but *co-creators* of informing systems, since their collaboration is required to create systems which are usable and useful in the first place. This perspective is reflected in work by many well-respected researchers in our field in addition to Nissen.

Enid Mumford focused throughout her long career (see, for instance, Mumford, 1983; 1995; 2003; 2006) on socio-technical systems design (ETHICS: Effective Technical and Human Implementation of Computer supported Systems), embracing the whole work system and not just artifacts. Participation by individual people and organizational groups in designing systems to work *for them* was crucial to successful design for Mumford. This idea is reinforced in work by Stowell on client-led design (Stowell and West, 1995), and by Ehn (1993) in relation to participatory design. We can also point to Checkland, whose work on the Soft Systems Methodology and its application to design of information systems placed emphasis on individual Weltanschauungen (worldviews or perspectives) as a key factor (Checkland and Holwell, 1998). Siv Friis work on client-controlled design (1991) placed emphasis on a need for those who would use a system to take ownership and control over the development process. A system that will be perceived as meaningful to particular people requires their input as co-creators in design, and consequently cannot be developed *for them* by anyone else, however expert.

As mentioned above, Langefors gave consideration to the phenomenon of needs creation in relation to design of systems (Langefors, 1995 p 26). It is interesting to reflect upon the phenomenon of desire in this context. Designers of systems frequently focus upon gathering data about the '*what*' of informing systems – what do these '*users*' need to be informed about? They also commonly engage with the '*how*' – e.g. what performance criteria must this system satisfy? However, the third category of data that designers need in order to create systems perceived as meaningful is often overlooked – '*why*'. Why might someone wish to engage with this informing system? What motivation is there for engagement? This third category of data must also be created and explored if IS developers are to take a holistic approach in building systems that can contribute to empowerment for use (Bednar and Welch, 2006). However, it is recognized that professionals are often constrained to work within assumptions based in [IS1]. Furthermore the emphasis in their work is often placed on efficiency and productivity rather than meaningfulness for particular clients. Developers and managers need scope to explore contextual dependencies with the clients themselves, to embark on a process of co-creation. Analysis by external agents is unsatisfactory. "New" systems analysis methods are required as the tools for sensemaking of their own practice and for interaction between the (system) members. These methods are different from those often assumed to be more conventional for IT professionals (e.g. Kosaka, 2008; 2009). We suggest that only clients themselves (e.g. specific stakeholders, actors, end-users, workers etc) are able to explore their (own) desires, based on contextually-dependent factors in *their* system for use [IS2].

Some models that attempt to explain '*user*' behaviour do so in terms of *acceptance* (e.g. the Technology Acceptance Model of Davis et al., 1989). Such models emphasise a passive role for people, who are perceived to be recipients of IT artefacts. Davis' model considers two main factors: perception of usefulness, and perception of ease of use of particular systems. This model has been criticised extensively by one of the co-authors of the 1989 paper (see Bagozzi, 2007) as failing to take into account a number of dimensions, psychological, philosophical and socio-cultural. Bagozzi does not argue that the model has no useful role to play in examination of systems for use. We agree with him, however, that it is insufficient on its own as a guide to successful introduction of informing systems. In our view, *desire* for systems that support people to inform themselves (or help others to do so) is contextually dependent and can only be satisfied through a process of co-creation, owned and controlled by those people themselves. Langefors discussion of people as information entities, who, together with data, are essential to formation of 'information systems' lends support to this view.

The concept of a *"system of use"* is in itself an important one. Peppard (2007) reminds us of a widespread fallacy that ownership of the 'right' IT systems will automatically lead to delivery of value for a business. He points out that information technology can only generate value if attention is paid to the design of the system for use at the same time that technological systems are developed. It is only at the level of the business that effective action can be taken to influence organizational values and behavior to enable effective use of available technologies. There is a paradox therefore in that, while elaborate and rigorous plans may be developed for implementation of the technology itself, it is relatively unusual to find similar plans in place for the *realization of benefits* from that technology. Ward and Peppard (2002) argue for an iterative process of benefits management. The view that IT 'resources' are a separate artifact that can be dealt with by 'experts' outside the main stream of business management leads to inherent difficulties. Evidence for these points can be seen in current popularity of the concept of IT Service Management. IBM, for instance, in their recent White Paper on ITSM, make a plea for organizations to recognize that IT management cannot be separated from management of the business itself (Salvage and Dhanda, 2007). Consequently, IT professionals need to understand business imperatives and be able to communicate effectively with other business managers *as an integral part of the same team.*

Philosophical Perspectives

The authors believe that theory and practice are indivisible, neither can progress without the other and they stand in a dialectic relationship.

What Radnitzky (1970) calls Continental or hermeneutic-dialectic (HD) schools of metascience share this position, whereas, according to Radnitzky (1970), Anglo-Saxon or logical-empirical (LE) schools strictly separate theory from practice (see overview Figure 3 and Table 1). Moreover, HD schools of metascience acknowledge the importance of history, which LE schools tend to ignore. In this context, we are not referring to history as a recorded sequence of past events, but as an on-going, continuous process of change in predefined variables (Langefors, 1966). We (the authors of this chapter) acknowledge that approaches based in Hermeneutic Dialectics recognize, not only individual uniqueness, but a need to avoid a Cartesian split in analysis. Any observation must be made by a particular observer, under particular circumstances, in a particular context (Maturana and Varela, 1987). It is not possible to separate observers from what is observed, in order to objectify/simplify analysis.

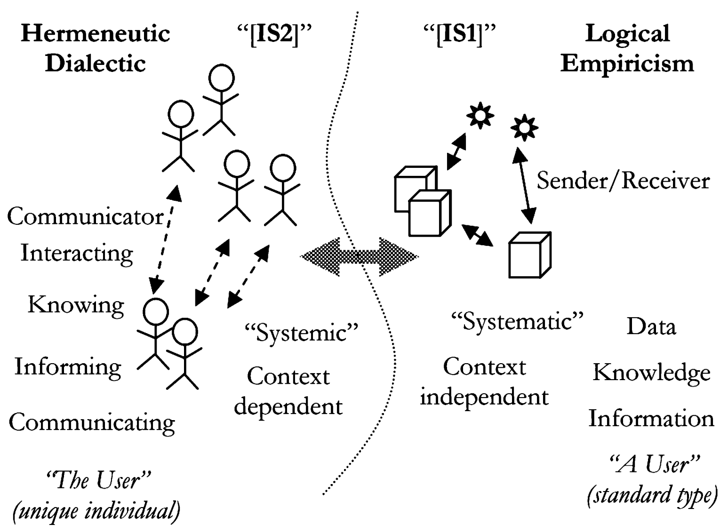

Figure 3: HD vs. LE

Inquiries based in an LE tradition are likely to give great attention to precision and clarity in expressing a problem situation. Radnitzky (1970) points to a danger within such inquiries that an artificial separation may arise between observations made and the unique perspectives of observer and observed. Adopting such a focus of attention could consequently lead to a loss of critical awareness and entrapment in confusion between specific and generalizable descriptions of experiences.

Table 1: Logical Empiricist and Hermeneutic Dialectic views (Bednar and Welch, 2008)

Feature	***Logical Empiricism***	***Hermeneutic Dialectics***
View of 'reality'	One observer independent reality; Reality is 'out there' to be discovered; Bias can and should be avoided as far as possible in order to get closest to this reality.	Many coexistent 'realities' dependent on observers; Understandings of 'realities' created through sense-making; Bias is a necessary part of individual sense-making processes – what enables people to make sense of their world.
Theory of truth	Correspondence theories predominate; Information can exist independently of human beings.	Coherence theories predominate; Information is created by individual human beings and cannot exist without them.
Historical context of data collected	Irrelevant because information is independent of any context. The object of research is assumed to lead to a given set of variables; Boundary of context is taken as given.	Relevant because selection of variables is dependent upon the choices made by individuals who collect the data; Boundary setting is a political process and questions to be asked are a matter of individual choice.

Causal connection s	Linear chains or trees; Efforts are made to define the parameters of a problem requiring rigorous inquiry; The domain of the problem space is taken as given; Focus is on rigor in inquiry.	Mutual, interlocked influences; Efforts are made to consider what the relevant problem space is, and how this is chosen. The domain of the problem space is selected by a human actor; Focus is on relevance in inquiry.
Values guiding research	Only those which are science-immanent; Objectivity, absoluteness and particularity.	Both science-immanent and external values; Subjectivity, plurality and relativity.
Separabilit y of theory from practice	Strictly separable; Objectivity follows from this premise. Subjective elements are excluded from the process of inquiry.	Theory and practice dialectically related; Subjectivity and relativity follow from this premise; They are inseparable and subjectivity is inherent in the process of inquiry.
Research interest	Technical research interests, potentially emancipatory; Desire to create a solution based on observation of objective 'facts'.	Mainly hermeneutic and emancipatory interests, can provide social techniques; Desire to create a resolution based on interpretation of interaction.
Main language features	Extensional and denotational; Messages, containing meaning (and knowledge) can be transmitted from a sender to a receiver.	Intentional and connotational; Messages are exchanged between an orienter and an orientee; meaning (and knowledge) is not contained in messages but is created by participants in an orientation process.

Researchers whose inquiries are based in philosophical practice from an HD tradition, on the other hand, are likely to make explicit recognition of uncertainty/ambiguity as features of socially-constructed perspectives on human activity. Their focus is likely to be on transparency, rather than clarity, emphasizing individual self-awareness. Applying metascience in informing science, and the relationship of these matters to Cohen's (1999) ideas, is discussed in greater depth by Nissen in Chapter 13 of this current work.

Individual learning may be described as taking place through sense-making processes as a response to messy and uncertain contexts in which resolutions are sought. Different orders of learning may be identified, based on a cycle of experience and reflection on experience (Argyris and Schon, 1974; Bateson, 1972). Higher orders of learning may involve reflection on sense-making processes themselves, i.e. a learning cycle may become transformed into a spiral. It is possible to describe reflection on sense-making as an exercise in practical philosophy, or investigation of the kind of 'philosophical doubt' described by Schutz (Wagner, 1970). The authors believe that certain points follow from this. First, if individual learning is a creative process based in sense-making, then context is clearly important. Any unique individual's view is based in reflection on experience (Bateson, 1972), and experience is context specific. It is suggested in this work, therefore, that an examination of contextual dependencies, as part of analysis, will be important. The Infological equation (Langefors, 1966) suggests that individuals develop unique understandings (meanings) by examining data in the light of pre-knowledge gained from reflecting on experiencing during a previous time interval. Furthermore, processes of reconstructing new understandings (meaning-shaping), by examining data in light of experience, may be what *constitute* organizations, their goals and cultures. For this reason, we consider it is inappropriate to speak of 'requirements capture' or 'requirements specification' in relation to the design process, as if there were some 'requirements' that are pre-existing. This was expressed by Bednar and Welch (2009, p 228) as follows:

"*Ways in which a problem is defined and redefined when perspectives shift will influence conceptualization and ultimately any proposed solutions. In our view, contextual inquiry forms and agenda for analysis in which individual perspectives can emerge and play a role in a creative process of requirements shaping* (Table 2)

Many researchers interested in informing systems 'design' have attempted to explore philosophical frameworks based in phenomenology (e.g. Mumford, 1983; Klein, 2006). These researchers recognized the existence of a double hermeneutic, in that they were dealing with autonomous human beings, who also attempted to make sense of their worlds. However, in order to take into account unique individual sense-making processes within an organizational problem arena, we suggest a need for analysts to explore *multiple levels* of contextual dependencies. Since it is not possible to explore a problem space directly from someone else's point of view, it follows that an external analyst/designer can only play a supportive role in enabling individuals within a given context to explore their own sense-making.

In the authors' view, exploration of multiple levels of contextual dependency may help to avoid entrapment in various types of reductionism: sociological, psychological or technological. It may also help to eliminate tendencies towards generalization, or substitution of an external analyst's own views for those of the participating stakeholders. Furthermore, we advocate attempts to go beyond grounding of research in phenomenological paradigms, recognizing a need for critically-informed understandings of problem-spaces. The authors suggest that, in order to avoid various types of reductionism and introduce 'philosophical doubt', analysts might attempt to incorporate philosophy as an integral part of their research practice (Bateson, 1972; Hirschheim et al., 1995).

Table 2: Nature of Inquiry

(Bednar and Welch, 2009)

Decontextualized	***Contextualized***
External analyst supports users in carrying out their problem definition.	External analyst supports actors in becoming analysts themselves.
Danger that solutions will be sought to problems described (pre-defined), not necessarily problems experienced by users.	Possibility for actors take ownership of the analysis. Solutions sought based on problems as experienced by actors.

A reductionist approach, emphasizing artifact design, ignores the possibility of emergent properties, which appear when individual behavior is considered in the context of systems. It is important to note that recognition of emergent properties of a system as a whole is insufficient. An individual actor acting within the context of a human activity system (of which an informing system may be viewed as one special case) may represent emergence of a different order. It is possible that the emergent properties associated with that individual may amount to more than those of the system as a whole, when considering the influence of other systems of which s/he is a component. For example, consider a fashion house as a human activity system. We might view a couturier as one contributing component, if we choose to draw a boundary around a 'system for supplying ladies clothing'. However, considered as a 'system for making profits by attracting customers to buy designer fashion wear', the emergent properties change, as the identity and reputation of the designer becomes an attracting influence (Bednar, 2007). As pointed out by Werner Ulrich in his discussion of boundary critique, perception of a system varies with the stance of the observer (Ulrich, 2001).

In some theories of sense-making, attempts are made to differentiate between an observer's and another actor's pictures of '*reality*'. See, for example, work by Dervin (1983). These views are not assumed to be complete or static. Instead, they are characterized by discontinuities. Individuals make efforts to bridge these gaps in a continual process of meaning-shaping. 'Information' might here be described as a sense-making/meaning-shaping continuity (re)constructed by a particular individual at a particular moment in time and space, through continual adjustments of perspective. Any observer must attempt to shape meaning in a particular situation by comparing different actors' apparent perspectives within given criteria, i.e. by carrying out a '*circling of realities*'. Thus, anyone wishing to inquire into informing system use must continually align themselves with an actor's perspective. For example, the meaning shaping in a particular situation can be described through a comparison of different actors' perspectives within given structural criteria. When we speak of '*circling of realities*', we refer to a necessity to acquire a number of different perspectives (in time-space) in order to be able to get a better and more stable picture of a particular actor's view of 'reality'. This actor's view of 'reality' is influenced by reflecting on interactions with other actors (Bateson, 1972). It is most important that those considering systems design recognize that they are setting up personal boundaries for a situation by defining it from their own experiences and preferences. We all have pre-understanding of phenomena, formed through the influence of our own values, wishful thinking, and how we as individuals have been socialized into a particular society. See, for instance, Langefors (1966) who discusses how information is created taking into account continuously evolving life experience; or Vickers (1972) who discusses the formation of what he calls 'appreciative settings' through a similar process. Bateson (1972) considers the impact of perception of 'difference' through continuous reflection upon sense-making. Information, for Bateson, represents a '*difference that makes a difference.*'

Awareness of this process, and attempts to focus upon the understandings and perspectives of the actors/stakeholders, are needed in shaping the requirements for design. The claim to take an actor perspective might seem to be unreasonable, but with the help of what is known as the 'hermeneutic circle', the pre-understanding is being reviewed gradually, with the support of ones experience. In other words there is a continual exchange/interchange between an individual's pre-understanding and experience, and it is within this process that inquiry may progress (Thuren, 1991). Furthermore, a dialectic emerges in such interactions, because each individual is concurrently interacting with others (Hermeneutic Dialectics). Hans-Erik Nissen draws attention to human perception of time (Nissen, 2007). He points out that on some occasions individuals see time as a linear progression from past to future. In other circumstances, however, individuals perceive time as a cyclical flow. For example we might consider the lifecycle of a frog. Frogs spawn in the spring; tadpoles hatch and grow into new frogs during the summer. These frogs either perish or grow strong during the year. In the winter, they shelter at the bottom of a pond, waiting for a chance to mate next spring, producing spawn. But we know that this is not the same spawn as before; it is the beginning of a new generation. Thus, it is not a life cycle but a spiral. We perceive a helix to form as a metaphor which combines both views of time.

The term 'sense-making' is intended to suggest the idea that people constantly meet gaps in meaning which need to be overcome. People move through life moment-by-moment, step-by-step, by experiencing. A step can be a re-occurrence of previous behaviors but, philosophically speaking, it is always a new step since it takes place in a new moment in time and space. Sense-making relates to that moment when a step in movement is halted and hindered because of all the discontinuities that surround us. We can reflect, like Heraclitus, "*No man ever steps in the same river twice, for it is not the same river and he is not the same man.*" This aspect of human experiencing creates a need to construct new meanings and understandings. In the context of our double-helix metaphor, users and designers must unravel how an individual interprets and overcomes this moment. Why was a gap experienced? How did the individual move strategically or tactically to overcome the gap? How did the individual continue her/his journey after the bridge building (Dervin, 1989)?

In this context, it is important to reflect upon the difference between a conceptual phenomenon and any particular instance of that phenomenon as it is experienced. For example, it is possible for two people to converse about the River Nile, each conceptualizing a similar phenomenon of a river passing through Africa to the Mediterranean Sea. This is, however, different from any particular lived experience of that river in space and time. It is through such confusion between conceptual phenomena and interpretation of lived experience that individuals may become entrapped in assumptions that requirements can be 'captured' – failure to engage with 'philosophical doubt' in relation to meaning-shaping can lead us into false steps when engaging in systemic analysis.

In the next section of the paper, we go on to consider how individuals experience systems in use, distinguishing between the characteristics of usability and usefulness, and exploring the linked processes of use and reflection upon use.

Thinking about Use

Different researchers have conceptualized the term 'information system' in a variety of ways. Nissen (1984), for example, points out that 'information systems' have two distinct dimensions, i.e. they usually include information technology and they are associated with *people* capable of acting as self-steering systems. Checkland and Holwell (1998), make a similar point, suggesting that not one, but two systems are involved – a system to be served (i.e. *people* engaged in activities), and a serving system containing elements which generate data useful to those people. Sauer also points out that an information system is not just an artifact, but that: *'Economic task, organizational, human relations / labor process and technical perspectives are all involved'* (Sauer, 1993, p 10). Claudio Ciborra (2002), points to a tendency within the field of information systems research to adopt perspectives suggested to be associated with outdated perspectives of natural sciences, which researchers proclaim to be 'objective.' Thus, systems professionals may be observing social phenomena and yet insist upon recording their observations using abstractions such as entity-relationship diagrams in order to preserve 'objectivity'. As Ciborra puts it: *"Thus, one tends to forget … the role of human choice behind the technical artefacts, and study the user side of IS by adopting the methods of natural sciences."*

The authors of this paper wish to highlight the confusion inherent in treating technical and social domains as if they are either alike or susceptible to 'objective' investigation. Furthermore, we believe use of the term 'information system' itself to be problematic, since it suggests that there is a commodity 'information' which can be readily transmitted from one person to another. Since human beings are required to take part in such a system in order to interpret data and transform it into something meaningful to them, we consider it preferable to refer to a system by which a person seeks to inform herself / himself as a *self-informing system.* Similarly, a system through which a person seeks to support others in informing themselves might be called an *informing system.*

Drawing on work such as Mumford et al. (1984) and Checkland and Holwell (1998), it appears to the authors that the question 'What is the purpose of an informing system?' is a relevant one to ask. Design of (i.e. human efforts to purposefully influence change or transformation of) an informing system, which is to be assessed as meaningful from someone's perspective, requires understanding (a process of meaning-shaping) as to what would make it meaningful for that person. However, if people are regarded as essential elements within an informing system, as the definitions above must imply, then a further dimension of complexity is added. *People* cannot be the subject of design by external professional developers. It may be possible only to contemplate design of *use* of an informing system (process), but not of the system itself. Borje Langefors (1966) pointed out in his Infological Equation that each individual creates meaningful information for himself. The equation **[I=i(D,S,t)]** shows how meaningful information [**I**] may be constructed from the data [**D**] in the light of participants' pre-knowledge [**S**] by an interpretive process [**i**] during the time interval [**t**]. The necessary pre-knowledge [**s**] is generated through the entire previous life experience of the individual. This can be viewed as a single helix of experiencing, interpreting and reflecting, because understanding is continually changing as time goes by. We might consider that this reflects Heidegger's words, that objectivity has meaning only for a subject who judges. It follows then that understanding of use is a matter of interpreting by the individual user concerned, through her sense-making processes. We would argue, therefore, that those individuals must own and control the process of development *for themselves* and cannot delegate such tasks entirely to an external professional 'designer'.

A key purpose for design of systems appears to be to change something for the better, as defined by some participant in, or observer of, that system. Such change may be seen as an emergent consequence from combined individual and organizational learning and sense-making processes (Bednar and Welch, 2005). In order for beneficial change to be brought about, both explicit and tacit organizational norms must be challenged. This requires users of ICT's and actors in organizational processes, both individually and collectively, to contemplate embracing the (as yet) unknown (Bednar and Mallalieu, 2001). Design efforts are contemplating a future problem space without any guarantee of success. Such challenges are often found to be uncomfortable by some participants in organizational life (see, e.g. Walsham, 1992; Argyris, 1990; Mumford, 2003) and thus a political dimension adds further complexity.

We do not intend, in this paper, to define human beings by their use of a technology or process. '*User*' should not be perceived as referring to people as important mainly in their role in using ICT artifacts. We prefer to write about '*workers*' or to use examples of names of people in their proper professions, when talking about people who use IT artifacts. This helps to break an unfortunate linguistic trend. On those occasions when we refer to '*users*' we do not intend to imply assumptions of common characteristics between collections of individual people who are 'users' of particular technologies.

People, as users, interact with ingenious creations of designers in the course of daily life. Each user's experience of use is unique and contextual. Descriptions of people's experiences as users may be made either by themselves or by other observers of use, e.g. analysts (formally or informally). As use is experienced, so descriptions of use will be interpreted by users and other analysts. Such interpretations will, in turn, lead to change in the experiences themselves in an unfolding process over time, e.g. the experience of driving a car for the first time cannot be repeated. The second drive is a different experience, influenced by interpretation of experiencing the first. Thus, experiencing use can be seen as a spiral, driven on by the interaction of experiencing and interpreting of experience (see Figures 4 and 5).

Living, experiencing and reflecting, individually and in various groups we perceive as on-going processes. This we have tried to indicate by the directed arcs suggesting a helix. The diagram shows two interacting helices, which may be described in the following way:

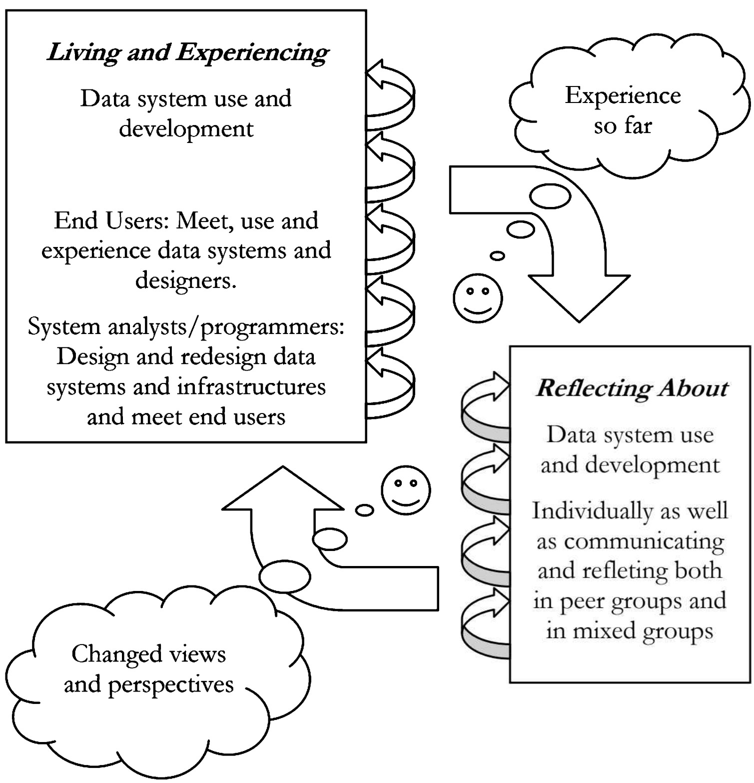

Figure 4: Experiencing and Reflecting

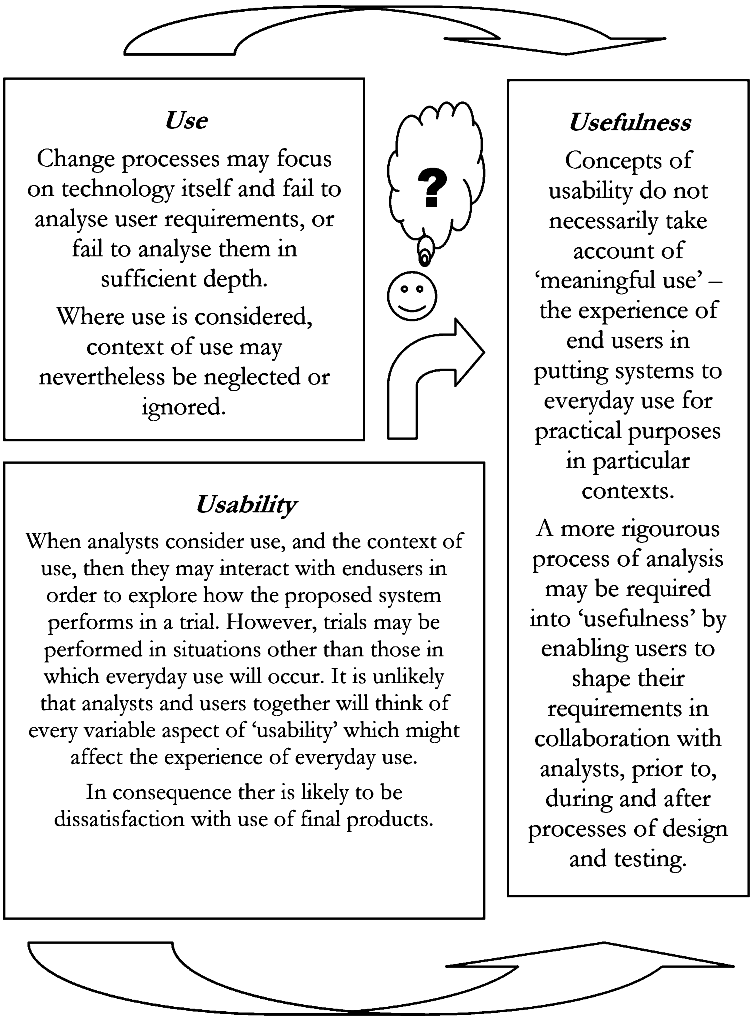

Figure 5: Experiencing Use

1. Helix one: *Living and experiencing.* This helix relates technological system use and design. End users meet, use and experience systems and their designers. Systems analysts / developers

design and redesign systems and infrastructures and meet end users.

2. Helix two: *Reflecting about* system use and design individually, as well as communicating and reflecting both in peer groups and in mixed groups.

We perceive each helix to influence the other. Thinking about use triggers interpretation of the descriptions of experiences made by users and other observers. Such interpretations trigger changes in experience of use and may lead to novel approaches to use, triggering ideas for further ingenuity in design.

Ingenious designers create new technologies aiming to satisfy the requirements of particular use. Such creative thinking begins a spiral in which reflections on use (by users and analysts interacting with them) can lead to modifications in design by focusing on usability (can an artifact satisfy the requirements of use?). Further reflections on usefulness (could the requirements of users be better satisfied than they are?) drive the spiral on by triggering further ingenuity in design. See Figure 5 for an overview of the relation between use, usability and usefulness.

In the context of informing systems, 'Use' reflects a purpose for the system (*what* someone wanted to achieve with it). Designers and developers will have a view of this purpose when they begin an intentional process of creative development. Reflecting upon this purpose as development progresses may lead developers (and/or other participants in the creative process) to consider 'usability' (*how* can the users be supported to pursue that purpose effectively / easily / pleasantly?)

Here, we can consider Gregory Bateson's concept of multiple orders of learning (Bateson, 1972). At lower orders, an individual attempts to make sense of phenomena in order to bridge an epistemic gap. Higher orders of learning occur when the individual reflects upon his own sense-making processes in this context, and upon these reflections themselves. We might see a focus on purpose (*what*) as an instance of what Bateson refers to as zero order learning, whilst reflection upon usability (*how*) may suggest a move to first order, i.e. involving reflection upon the process by which the *what* is achieved.

However, this does not appear to go far enough. Bateson refers to 'informing' in the following way:

"*The explanatory world of* substance *can invoke no differences and no ideas but only forces and impacts. And, per contra, the world of* form *and communication invokes no things, forces, or impacts but only differences and ideas. (A difference which makes a difference is an idea. It is a 'bit', a unit of information.)*" (1972, p. 272/3).

Our purpose in highlighting these terms (use, usability and usefulness) is to focus upon *cognition*. In order to cognize, we must be able to recognize a phenomenon, i.e. to perceive a difference. Each individual who seeks to make use of an informing system has reasons of her own for doing so, which are both unique and contextual. It is this that we refer to when we use the term 'usefulness' – not *what*, or *how*, but *why* does the individual engage as a participant in the informing system (Bednar and Welch, 2006). This is the difference that makes a difference for her

Unless designers reflect upon 'usefulness' (*why and from whose perspective?*), it is likely that their creative process may focus upon a different problem space than that which is of genuine concern to problem owners (intended 'users'). Consider, for example, a number of well-publicized cases of organizational ICT developments that have failed to deliver the benefits expected from them. In some cases, participants within organizations have reflected that problems arose through conception of the development process as occupying a technological or socio-technical problem space, ignoring cultural dimensions. A shift of perspective on the nature of the problem space has sometimes enabled 'success' to become achievable. We find evidence for this position, for instance, in an experience of Nestlé. In 1998 the company began a project to introduce an Enterprise Resource Planning system (Worthen 2002). Problems were experience in implementing the new system and after approximately two years, during which it proved impossible to achieve the desired functionality, Nestlé managers realized that what they had initially seen as a purely technical venture was actually engaging with the culture of the company in a negative way. The project was then restarted, taking into account the social as well as technical dimensions of the desired changes. The results this time were found to be more successful. Another example comes from Marchand and Hykes (2006). Here, developers of a new system were congratulated upon a successful project, coming in on time and within budget with apparent functionality. However, it took the company's auditors to point out that the project had really failed – few people were actually using the new system!

A further inhibitor of success in such projects may be attributed to an undue reliance on rational planning methods as a basis for decision-making, when actually such methods fail to surface the real, contextually-dependent desires of the actors concerned. Support for this proposition comes from Bateson (1972, above) and also from work by Lindblom (1959) in which he refers to 'muddling through' rather than rational planning as a more accurate descriptor of organizational decision-making. Ciborra (1992) also discusses this phenomenon when he refers to 'bricolage' (see below).

C. West Churchman's (1979) expressed a similar view, as follows:

"*We see again the tragicomedy of rationality pushed beyond the boundaries of its domain. Reflection is one of the strongest instruments of rationality and is also its enemy. When reflection is allowed full sway, then can we really say that the rational approach is the best way of using the human intellect to improve the human condition?*" (Churchman, 1979, p. 152).

When Churchman describes human efforts to negotiate this dilemma, he proposes:

"… *a beginning attempt to say something about an inquiring system that does not feel impelled to choose the best in a class of approaches to the problem of human destiny and yet does not at the same time fall into the trap of relativity*" (1979, p.152).

Experience of living can lead in many different, unexpected directions that cannot be planned or managed in advance (Heidegger, 1962). It follows that any process of design that focuses only on specific purposes (*what and how*) is unlikely to be experienced as satisfying by intended 'users' of the system. In work related to application of formal methods, Claudio Ciborra points out two alternative strategies which developers of an informing system could choose to adopt.

When faced with a novel problem space, a person might first try to make sense of it in a context of her previous experiences in seeking for resolutions. Beginning within familiar competences, and gradually 'tinkering' and moving outwards from this base, she might only turn to wider or more formal sources of unfamiliar 'knowledge' if her existing competences prove insufficient to the task (see Ciborra, 1992). This first type of strategy, Ciborra refers to as *bricolage*, or improvisation. Similar observations can be recognized in the work of Ehn (1993) related to efforts of going beyond Participatory Design. Ciborra relates the concept of improvisation to the complex world of open source, and how the phenomena of open source as a community has been able to deal with increasingly complex and dynamic software development, through 'hacking'.

This may be contrasted with commonly specified purposes behind more formal information systems methodologies, which assume orchestrated efforts in 'information systems' analysis and development. Such methodologies have an appeal to organizational managers in that they appear to offer a possibility of exercising control over resource expenditure, together with the possibility of applying concrete measures of performance with which to evaluate success. However, we suggest that they offer only the illusion of good stewardship, since many formal projects fail to deliver value to the business in practice (see e.g. Marchand and Hykes example mentioned above). Bartis and Mitev (2008) illustrate this how power relations within an organization can influence perceptions of 'success' or 'failure' in the governance of projects, regardless of the perceptions of the actual users. Referring to their work relating to a project in a large multinational company's operations in a central-eastern European country, they say:

…the dominant coalition claimed project success. While the key users did not use the system as intended and the project goals were not achieve, the project committee reported success to the top management board' (Bartis and Mitev, 2008, p 112).

We can reflect that hermeneutically-informed, phenomenological approaches to analysis are a necessary part of the double helix described earlier. In a method for contextual inquiry, such as the Strategic Systemic Thinking framework (Bednar, 2000), we can see a multitude of different roles for users (and other actors) as analysts. They may make descriptions of their own sense-making and experiencing, and reflect upon them. The external analyst (e.g. consultant), on the other hand, both observes her/his own experiencing and assists users (or other actors) in making their descriptions and interpretations. Figures 4 and 5 draw attention to the thinking / reflecting about use side and presents different dilemmas of system analysis/design as against system use.

In the next section, we examine the formation of productive learning spirals in the light of Gregory Bateson's concept of multiple orders of learning. We go on to explore possible methods for promoting learning through exploration of multiple levels of contextual dependencies.

Double Helix

Informing systems can be discussed as systems of information. Efforts to develop the quality of such systems would incorporate reflection over processes of informing oneself, informing others or facilitating others to do so. This reflection forms part of a learning process. As we have seen, Gregory Bateson (1972) put forward a concept of multiple orders of learning. At lower orders, an individual attempts to make sense of phenomena in order to bridge an epistemic gap. Higher orders of learning occur when the individual reflects upon his own sense-making processes in this context, and upon these reflections themselves. We might again consider this to involve the creation of a double helix. Zero and first order of learning we relate to the 'first' helix. The second order of learning we see related to the second helix. When Bateson remarks on his description of order he suggests that 'the talking and thinking about' the second order, in its own right, would be outside of the taxonomy. In a sense it would be 'parallel' to it or possibly something which could be described as Order 2.5. Reflection as part of efforts to develop the quality of an informing system can be seen to incorporate a number of facets, such as informing environments (at different levels), delivery systems involving particular technologies and problem specific contextual dependencies. These facets are similar to those explored by Cohen (1999) in his Informing Science framework.

When referring to the metaphor of double helix, we could imagine that when we, as observers, discuss this (as a metaphorical phenomenon) we might do it from a perspective within a 'third' external helix. We might reflect with Gregory Bateson that there is a double bind in our thinking which relates to the double helix theme. As conscious human beings, we have no choice but to reflect (see Figure 6). Bateson suggests that efforts to adopt a third party perspective (an imaginary outsider parallel) may help to break out of double bind, i.e. in our view an observer perspective brings out creation of a triple helix. (For a discussion of Bateson's double bind theory, see later in this chapter).

Figure 6: Example of Double Bind

(Hay, 2001; 2007a)

Werner Ulrich (2001; 2006) discusses research as a means to promote reflective societal practice He points to three indispensable qualities for *reflective competence* (in relation to one's own claims and those of others). It must be:

> 1. *Self-critical:* the effort of systematically examining one's own premises through self-reflection and dialogue, with a view to carefully qualifying the meaning and validity of one's claims;
>
> 2. *Emancipatory*: working actively to help others in emancipating themselves from one's claims, as well as from theirs; and
>
> 3. *Ethically alert*: making transparent to oneself and to others the value implications of one's claims, and limiting these claims accordingly (Ulrich, 2006, p16).

To us, Ulrich's three qualities described above reflect the same characteristics of critical systemic thinking that we recognize in the work of Gregory Bateson, i.e. a focus on self-emancipation through systemic meta-reflection from unique individual perspectives of autonomous and self-reflecting systems.

The question for us all to address is how we should conduct hermeneutically-informed, phenomenological inquiry into human activity systems in a practical setting. We discuss some examples of approaches which attempt to do this, below. The first of these relates to the specific context of professional practice in systems analysis. Here the focus is on inquiry into complex problem spaces in an organizational setting (e.g. ICT development as an instance of organizational change). The second example focuses on image as a therapeutic catalyst in the context of dysfunctional relationships within human activity systems.

The Strategic Systemic Framework (see Figure 7) is an example of an approach to contextual inquiry that may be helpful in empowering individuals to break out from prejudices and explore their own perspectives in order to escape from a double bind (e.g. Bednar, 2000). The process of the SST framework includes three, interrelated aspects (intra-analysis; inter-analysis and value analysis). All aspects incorporate tools and techniques that support actors, both in the process of elaboration and in the process of categorization of messages.

The intra-analysis aspect is intended to support creation of a learning spiral, as actors are supported to reflect and think about a problem

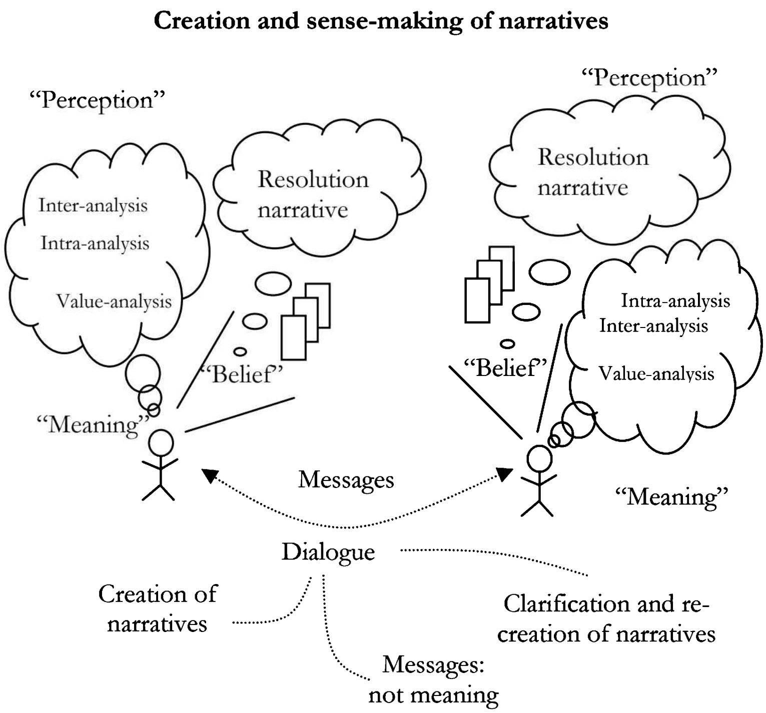

Figure 7: Sense-making in the SST framework

space with this collection of tools and techniques. In inter-analysis, actors are supported in creating a learning spiral that focuses on communication of their individually-created narratives, and sense-making of others' individually-created narratives. In value analysis, actors are supported, both individually and in group interaction, to create a learning spiral that focuses on reflecting and thinking about the scale of 'measurement'. What is worthwhile as a scale of comparison for evaluating narratives, and assessing how they will be evaluated?

Bednar and Welch (2009. p. 229) comment on the issue with the following:

"The concept of contextual dependency is of interest because it supports a focus of inquiry on unique individuals, and their beliefs, thoughts and actions, in specific situations and contexts. This kind of inquiry is intended to provide support to individuals in a contextually dependent creation of necessary knowledge. This in turn enables successful communication, analysis and, eventually, IS development to occur."

All three aspects together are intended to support people in creating a frame of reference for reflection over their process of inquiry. Each aspect may be described using the metaphor of a helix; and together they 'form' an intertwined, double helix upon which participants may reflect.

Unfortunately, in organizational life as it is experienced, phenomena occur that can inhibit higher orders of learning (as described by Bateson, 1972) and prevent the formation of creative learning spirals such as that reflected in the double helix metaphor.

Argyris (1990) highlights a concept of 'defensive routines' in relation to organizational behavior. From time to time in organizational life, people are confronted by a need for uncomfortable choices, or have to give one another 'bad news. Often, they prefer to avoid unpleasantness and/or conflict in their workplace, and so they become quite skilled in adopting routines of avoidance. Argyris coined the term 'skilled incompetence' to describe such phenomena. These routines have an effect of ensuring that the status quo is maintained, and difficulties appear to be addressed when practically they are ignored. Argyris points to a discrepancy that often occurs between espoused theories (i.e. what people think they do) and theories in use (what it appears to other people that they do in practice). A variety of emotional responses called forth by experience of organizational life may conflict with each other, or may conflict with more reasoned assessments of necessary action.

The phenomenon of defensive routines represents an emotional, rather than a rational response. People exhibit neither perversity nor stupidity in adopting these routines but pursue them while scarcely aware that they are doing so. Argyris observes that, even where there is a positive organizational discourse about change, defensive strategies may operate to block progress with projects or plans designed to affect it. Further support for this view comes from Brunsson (2002), who points out how organizational discourse (talk) may be at odds with decisions and actions taken. He describes a phenomenon of 'hypocrisy' that is similar to Argyris' idea of defensive routines – decisions are sometimes taken in order to avoid action, rather than to bring it about. However, Brunsson's view is that conflict within organizations is healthy, and that it may be better for problems to remain unsolved, since this leads to more opportunity for reflection and discussion (what Argyris might term opportunities for double-loop learning to occur). In Brunsson's words:

"Insoluble problems are a splendid vehicle for the reflection of many ideas and values. They can be endlessly discussed from all sorts of angles and without ever reaching a conclusion. Solutions that can reflect an equal variety of ideas are rare indeed" (2002, p.23).

Clearly, the potential for defensive routines to emerge will depend very much on individual and organizational sense-making processes and their expression in organizational culture. Weick (1995) comments as follows:

"What is unique about organizational sensemaking is the ongoing pressure to develop generic subjectivity in the interest of premise control and inter-changeability of people. Generic subjectivity is developed through processes of arguing, expecting, committing, and manipulating. These four processes produce roles that create interchangeability, and they produce arguments, expectations, justifications, and objects that become common premises for action. These same four processes dominate the more intimate intersubjective interactions where innovations in arguments, expectations, justifications, and objects are formed" (Weick, 1995, p.170).

We see similarities between the perspectives of Argyris and Weick and Gregory Bateson's work on double bind theory (Bateson, 1972). It is interesting to compare the following discussion of this theory with the quotation from Weick, above:

"Psychologists commonly speak as if the abstractions of relationship ('dependency', 'hostility', 'love', etc) were real things, which are to be described or 'expressed' by

messages. This is epistemology backwards: in truth, the messages constitute the relationship, and words like 'dependency' are verbally coded descriptions of patterns immanent in the combination of exchanged messages …

"But to act or be one end of a pattern of interaction is to propose the other end. A context is set for a certain class of response.

The weaving of contexts and of messages which propose context – by which, like all messages whatsoever, have 'meaning' only by virtue of context – is the subject of the so-called double-bind theory" (Bateson, 1972, p.275).

The theory of double-bind deals with a phenomenon of transcontextuality, in which the weaving of messages which propose context leads to 'tangles' in the rules for making transforms and consequently individual sensemaking processes experience confusion. Bateson points out (1972, p.273) that all organic systems (of which people are an example) are capable of adaptive change. Thus, they are capable of deuteron-learning:

"*Whatever the system, adaptive change depends upon feedback loops, be it those provided by natural selection or those of individual reinforcement. In all cases, then, there must be a process of trial and error and a mechanism of comparison.*

But trial and error must always involve error, and error is always biologically and/or psychically expensive. It follows therefore that adaptive change must always be hierarchic.

There is needed not only that first-order change which suits the immediate environmental 9or psychological) demand but also second-order changes which will reduce the amount of trial and error needed to achieve the first-order change. And so on. By superposing and interconnecting many feedback loops, we (and all other biological systems) not only solve particular problems but also form habits which we apply to the solution of classes of problems.

We act as though a whole class of problems could be solved in terms of assumptions or premises, fewer in number than the members of the class of problems. In other words, we (organisms) learn to learn, or in the more technical phrase, we deuteron-learn" (Bateson, 1972, pp 273/4).

Difficulties arise for us as human beings when the habits we form through deuteron-learning come about through the confusion of double-bind. Acting upon taken-for-granted assumptions about the class of problem a particular context represents, we may be led unawares to take those false steps described by Argyris as 'skilled incompetence' or 'defensive routines'. In effect, we are learning how not to learn. Reflecting in the context of alcoholics' efforts at recovery through the programmes of Alcoholics Anonymous, Bateson goes on to point out that escape from double bind requires establishment of a new personal epistemology in the subject. He discusses the impact of the Serenity Prayer with which each meeting of AA is commenced: *Grant me the serenity to accept those things that I cannot change, the courage to change those things that I can, and the wisdom to know the difference.* Bateson comments:

"If double binds cause anguish and despair and destroy personal epistemological premises at some deep level, then it follows, conversely, that for the healing of those wounds and the growth of a new epistemology, some converse of the double bind will be appropriate. The double bind leads to the conclusion of despair, 'There are no alternatives'. The Serenity Prayer explicitly frees the worshipper from those maddening bonds" (Bateson, 1972, pp 334/5).

We reflect that, in order for individuals to escape from the double bind that leads them to adopt Argyris' defensive routines, a converse influence is required to enable them to challenge taken-for-granted assumptions. Brunsson's argument for the benefits of insoluble problems (Brunsson, 2002, p. 23 cited above) may be viewed as an example of such a converse influence. Another, we suggest, is provided through the concept of 'diversity networks' in relation to the Inter-analysis aspect of the SST framework (Bednar et al., 2008). An essential principle underpinning Strategic Systemic Thinking is that individual people are not constrained by a need for bi-valued logic. In everyday life as it is lived, we do not always respond to a question with 'Yes or No' or 'True or False' but often we answer 'It depends' or even 'Yes <u>and</u> No'. Human beings have no difficulty in holding in mind values or propositions that conflict (see Table 3).

Table 3: A model of four-valued logic (e.g. paraconsistent logic)

Assertion of Negative Belief 'I do not believe that a resolution for this problem space can be achieved'	*Assertion of Possible Belief* 'I believe there it may be possible to resolve this problem space, but I don't currently know how'
Assertion of Positive Belief 'I believe that a resolution for this problem space can be achieved'	*Assertion of No Belief* 'I can offer no opinion whether or not a resolution for this problem space can be achieved'

Thus, in any problem situation, a human being can contemplate a paradox within or between particular proposed resolutions. However, many vehicles for organizational decision-making, be they meetings to discuss a problem situation or systems designed to provide support to decision-takers, are based on a presumed need for consensus around non-paradoxical solutions. A key purpose of the SST framework is to support creation of a rich 'knowing'-base about problem situations, which takes into account individual perceptions of contextual dependencies at multiple levels. A process for creating such a knowing-base, such as SST, includes support for postponement of any search for consensus while actors explore their own and one another's understandings. The framework supports employment of several levels of four valued logic in order to create representations of 'diversity networks', i.e. overviews of the range of opinion among a group of interested actors, arising from their individual narratives created in their Intra-analyses.

The first level in creation of a diversity network is formed when individual actors explore their personal, contextual analyses of a problem scenario. Table 1 shows that a range of possible responses emerges. Each individual's articulated narrative can be classified during inter-analysis by means of these four values. It is then possible to progress to a second level, in which those narratives expressing positive or possible belief are fed back to the whole group of actors. Each then creates her own narrative about that particular possible resolution. These responses can again be classified according to the four values shown in the Table. The process is repeated for each positive assertion, building a diversity network. This becomes a depiction of the collective, individual 'knowing' within the group upon which they may reflect further in seeking for resolutions. This is, of course, an idealised view of a process because, once an inquiry is on-going, it becomes a dynamic, flexible and ever-changing phenomenon.

Another approach supporting individuals to break out from entrapment of mind can be found in the work of Hay (2001; 2007a; 2007b), relating to image as a therapeutic catalyst. Here, she uses visualization of an outside perspective to support individuals caught in a double bind in e.g. dysfunctional family relationships through games using computer animation. It reflects Gregory Bateson's idea of an "Infinite dance of changing coalitions" (Bateson, 1972; pp 240-242), which is itself a translation of Von Neumann and Morgenstern's game theory.

Human sense-making is the essence of the creative dialectic in the helices to which we refer. We reflect that the concept of senses can be used in different ways. We might understand our senses to involve the input of perceptions of lived experience to our human consciousness, i.e. the 'now'. However, it is also possible for us to conceive of senses as those of the imagination and human emotions (e.g. as conceived by in contexts of art, emotional intelligence, etc.). Here, the senses are released from 'now' and can 'experience' the past or the future as well. Why is it difficult to connect reflection with use (or reflection on analysis with design practice)? This may be due to cultural and social aspects of our environments.

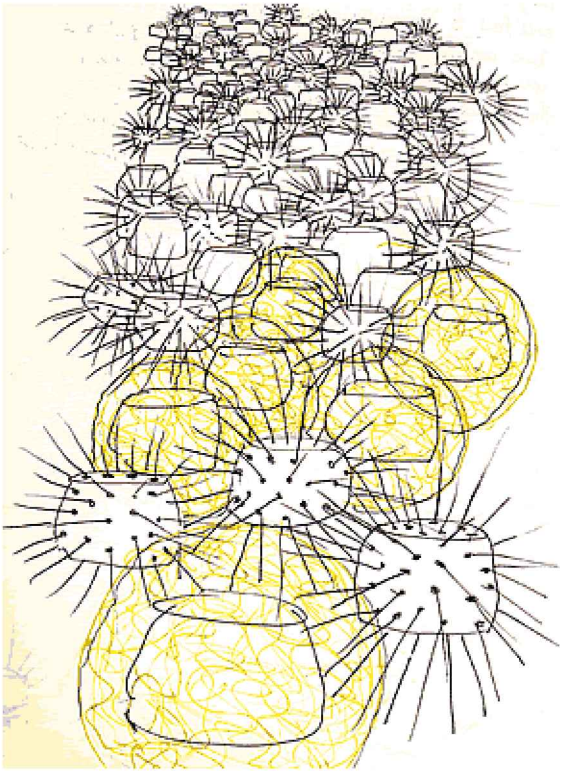

Figure 8: Society and Double Bind.

(Hay, 2001; 2007a)

Figure 8 is an illustrator's view on the double bind in society (Hay, 2001; 2007a). It shows marshmallows (representing individual people) caught in a double bind. Each 'soft' marshmallow experiences 'pain' in its encounters with 'spiked' fellows. As a response, it grows spikes of its own. When marshmallows with spikes get together they are more prone to get stuck, reflecting entrapment.

We can draw a parallel with entrapment of mind which can occur when human individuals espouse a paradigm equating to Bateson's first order learning and are not able to move beyond to embrace second order learning (e.g. reflection on thinking):

'Individual emergence could mean unraveling entrapment through the identification of double binds and 'mixed messages', in short the re-learning of leveling patterns of communication and there is an irony that this can be done through therapy using double-binds' (Hay, 2001; 2007a).

Hence, efforts at reflection on ones own behavior from an observer's stance might break into this cycle of harmful responses and encourage a beneficial dialogue. This can be viewed as breaking away from a single helix of experience, interpretation and reflection.

In both the examples discussed above, we can see how individual understandings, and reflection over these understandings, are continually changing in interaction with other people as time goes by. It is for this reason that we highlight a need to consider multiple levels of contextual dependencies. We might also consider, paraphrasing Heidegger's words, that inquiry into usability and usefulness has meaning only for the particular subject who judges (e.g. Heidegger, 1962).

Conclusions

In this paper, we explore the proposition that separation of (and confusion between) reflecting over use and usability, on one hand, and usefulness on the other, are open to question. We see support for this view in discussions such as that referred to in the 6th annual National Colloquium for Computer Security Education 2002:

Most representatives and speakers talked of information assurance programs at the bits and bytes level, with research agendas heavy on technology, including loss leaders like public-key infrastructure. And while speakers touted forensics programs, intrusion-detection and prevention programs, security standards development and other technical programs, there was little talk about business value and critical thinking. (Radcliff, 2002*)*

It appears that there were a few individual speakers, such as Professor Nimal Jayaratna, who deviated from the main stream and suggested that '*We need a fundamental re-think about security education issues*'. Some educators, like Alexander Korzyk '*questioned whether information security should remain in the computer science discipline at all or be moved to areas of study more reflective of business risk issues*' (Radcliff, 2002).

This is to us another example of the great importance we ascribe to reflecting on overall usefulness from end users' points of view. However, it is not obvious how reflecting would be encouraged in practice. We believe that the metaphor of the double helix described in this paper may provide a vehicle for discussion - a step in the right direction.

In this paper, the authors have attempted to draw a distinction between the dialectic relationship of experiencing and designing of artifacts/processes, such as communication and information technology devices, and the more complex relationship which must be surmised to subsist between use and design in informing systems. We have done this by highlighting differences between the terms use, usability and usefulness in this context. The inherent complexity of such processes is a function of the nature of informing systems as a special case of a human activity system, in which people form an essential part of the system itself. The double helix metaphor is considered by the authors to be helpful as a means to examine complexities in such a relationship. The contribution of this paper is to support systems analysts in their efforts to cognize, and to recognize, continuities of experience and reflections upon experience in their practical inquiries.

From a philosophical perspective, the authors have highlighted the importance of a hermeneutically-informed, phenomenological approach as a means to challenge presuppositions which might be taken for granted. Such an approach also helps us to avoid a fallacious emphasis on objectivity, which is inappropriate when examining individual reflections on experiences (use of the plural 'experiences' here is intended to emphasize the uniqueness of individual perspectives). Dangers involved in an artificial separation between observations made and the unique perspectives of observers, leading to a loss of critical awareness are also highlighted. Methods of inquiry based in multiple levels of contextual inquiry are suggested as a means to empower individuals to reflect upon their experiences of use. In developing informing systems, they need to consider not just *what* and *how* and *on whose behalf*, but also the *why*, and *from whose point of view* – as this reflects the difference that makes a difference.

We have introduced two examples of approaches to inquiry into human activity systems which draw upon hermeneutically-informed, phenomenological perspectives. These are the Strategic Systemic Thinking Framework (Bednar, 2000) and image as a therapeutic catalyst (Hay, 2001; 2007a; 2007b). Both of these exemplify efforts to put critical systemic thinking into practice, influenced by work by Gregory Bateson.

Individual and collective sense-making processes are discussed in relation to learning about experiencing use in relation to designing. The authors discuss a need to go beyond the concept of the 'hermeneutic circle'. We discuss how an individual gradually reviews her own pre-understandings, with the support of experience, in a continual exchange/interchange between those pre-understandings and experience. Additionally, it is necessary to include interactions between individuals as a part of the analytical process. A recognition that people are reflecting and experiencing in interaction with other people (who are also reflecting and experiencing) supports awareness of a double hermeneutic through which a dialectic emerges. It is only through this recognition that critically-informed, systemic inquiry is enabled to progress. We perceive the phenomenon of a continuing flow of human experiencing and reflecting, not as a circle, but as a multifaceted spiral of learning about, and experience of, use, usability and usefulness over time.

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PART IV: APPLICATIONS OF INFORMING SYSTEMS

Chapter 15

An Information System for a Bauxite Mine

J.E. Everett

Introduction

Bauxite is mined and transported by conveyor to a processing plant, screened and washed, then placed into blended stockpiles to feed the alumina refinery. While being stacked to the stockpile, the ore is sampled. Completed stockpiles must be acceptably close to target grade (composition), not only in alumina, but also in residual silica, carbon and sodium carbonate.

The mine is an open-cut pit. Each day the choice of ore to mine, from multiple locations in the pit, is based upon estimates of grade. Estimated grade, from exploration drilling of the area before mining, has both systematic and random error.

This chapter describes an information system to guide the daily choice of ore to mine. Continually updating the comparison between forecasts and sampled product, the system provides adjusted forecasts. Ore is selected to bring the exponentially smoothed grade to target, in each of the control minerals.

In Chapter 2, Cohen (1999) models Informing Science as 1) Design and Conceptualization: the creation of new patterns of informing; 2) Instance Creation: the construction of informing systems according to an established design, and 3) Operation: the informing activities of the completed system.

In this and similar applications I have found Cohen's model benefits by emphasising a two-way flow in the development process. The "informer" provides expertise but the client, just as importantly, provides experience heuristics. This enables the mutual development of a system for which the client has ownership. Actual and psychological

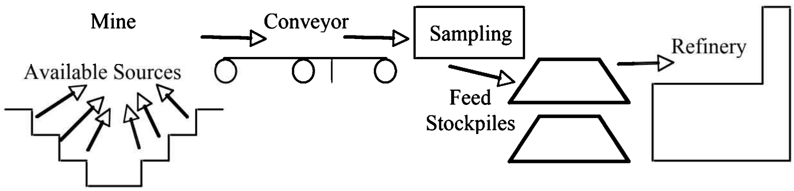

Figure 1: The flow of ore from mine to refinery

world's largest producer. The Australian aluminium industry directly employs over 16,000 people. (Australian Bureau of Statistics, 2006). The International Aluminium Institute, (2000) provides a summary description of the bauxite mining and refining processes.

Figure 1 shows the flow of ore from mine to refinery. The ore is mined from an open-cut pit, from the various pit faces available at the time. For each 12-hour period, the mine planner must decide the amount of ore to be selected from each available source. Each available source has an estimated grade vector in a range of minerals, of which the four most important are alumina, reactive silica, carbon and oxalate. The grade estimate for each source is the "mine forecast", based upon sampling from exploratory drill holes before mining.

The mined ore travels over 50 km on a conveyor belt to be crushed and sampled before being used to build stockpiles, typically of 200kt. The stockpiles are built by "chevron" stacking back and forth, and reclaimed from one end in such a way that each stockpile can be assumed to be of uniform grade.

The refinery uses the Bayer process (Habashi, 2005) to convert the bauxite ore to pure alumina. Efficient operation of the refinery depends upon the bauxite feed having consistent grade. It is therefore important that the stockpiles from which the refinery feed is drawn each have grade within a tight range of target, in each of the four minerals.

To achieve the required stockpile grade, the ore selected each day must be chosen appropriately. This is a difficult task, because the ore grade is not known accurately until the ore has been mined, crushed, sampled and assayed. Before mining, the grade of each available source must be forecast from the assays of samples previously taken from quite widely spaced exploration drill holes. An adjusted forecast is calculated, by comparing the recent forecasts with corresponding production sample assays.

Selecting ore to bring each individual stockpile to target requires very tight operational coupling between the mining operation and the building of stockpiles, to ensure that material designed for a particular stockpile goes to that stockpile. The improved system to be described here is operationally decoupled by instead selecting ore each shift so as to bring the exponentially smoothed grade back to target. The Continuous Stockpile Management System (CSMS) being applied was originally developed for iron ore production (Everett, 1996; Everett, 2001; Kamperman, Howard & Everett, 2002).

The CSMS achieves operational decoupling but tight information coupling between mining and stockpile building.

In selecting ore to be mined, it is chosen to have adjusted forecast grade such that the exponentially smoothed continuous stockpile is as close as possible to target grade. As the ore is mined, the smoothed stockpile grade is updated to incorporate the adjusted forecast grade of the newly mined ore. When that ore is sampled and assayed, the exponentially smoothed continuous stockpile grade is revised accordingly.

The continuous stockpile grade, and the forecast adjustments are both calculated using exponential smoothing, a widely used forecasting technique (Hanke & Reitsch, 1998). However, the two applications of exponential smoothing differ from each other, and from the usual published applications, as will be described below.

The Continuous Stockpile

Discussion with the operating staff confirmed that previous practice had been to attempt to build each individual stockpile to target grade. This led to cyclic behaviour, with weak attention being paid to grade at the start of a stockpile, and strong attention near its completion. Since the building of stockpiles was remote from the mining operation, this required an unachievable tight operational coupling between mining and stockpiling.

The next step was to consider a moving average over the stockpile size. For example, since stockpiles are built to 200kt, then the goal is to keep the grade of the most recent 200kt close to target.

Let P_n be the production grade for shift n. S_n is the stockpile grade at shift n, calculated as the moving average over the past k+1 shifts, up to and including shift N. W[n] is the kilotonne production in shift n. P_n and S_n are vectors, because we are concerned with the grade of the four minerals {bauxite, reactive silica, carbon and oxalate}.

$\underline{S}n = N\text{-}k\sum N\underline{P}n / N\text{-}k\sum NW[n]$, where $N\text{-}k\sum NW[n] = 200$ for a 200kt stockpile.

However, a moving average has undesirable informational qualities. Information is treated as equally important until it is suddenly given no further weight. This means that a sudden anomaly generates an appropriate effect when it enters the moving average, but also generates a spurious equal and opposite effect when it leaves the moving average.

A further improvement is to use an exponentially smoothed average. For this, all past information is included, with exponentially declining influence. Let $\underline{P}'_n$ be the exponentially smoothed mean up to and including shift n, smoothed at the exponential rate α_1 per kilotonne.

$\underline{P}'n = \alpha n\underline{P}n + (1\text{-}\alpha n)\underline{P}'n\text{-}1 = \alpha n\underline{P}n + (1\text{-}\alpha n)(\alpha n\text{-}1\underline{P}n\text{-}1 + (1\text{-}\alpha n\text{-}1)(\alpha n\text{-}2\underline{P}n\text{-}2 + \ldots.$

In textbook applications of exponential smoothing (e.g. Hanke & Reitsch, 1998) the time (or weight) intervals are generally all the same, so all α_n values are identical (and expressed as a). But in the situation being considered here, the tonnage W[n] being mined will vary between shifts, so α_n must be adjusted accordingly. It can be shown that the appropriate α_n is given by:

$$\alpha n = 1 - (1\text{-}\ \alpha 1)W[n]$$

For a moving average across a stockpile size of Q kilotonnes, the average "age" of the ore is Q/2 kilotonnes. For an exponentially smoothed stockpile, the average "age" of the ore is $1/a_1$ kilotonnes. So to emulate a stockpile size of T kilotonnes we should use a smoothing constant a_1 per kilotonne, where:

$$\alpha 1 = 2/Q$$

Thus, for a CSMS to be equivalent to a stockpile size of 200 kilotonne, α_1 should be 0.01 per kilotonne.

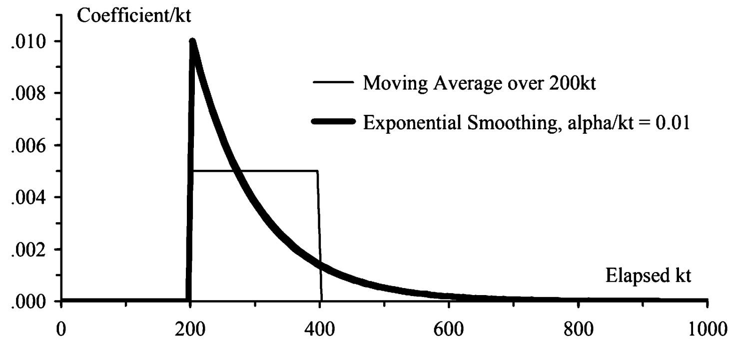

Figure 2: Moving average and exponential smoothing in the time domain

Figure 2 compares moving average and exponential smoothing in the "time" (or tonnage) domain. The effective coefficient applied to a kilotonne of ore is graphed against the tonnage of elapsed ore. The moving average coefficient per kilotonne stays constant until it discontinuously collapses to zero, but the exponential smoothing coefficient declines exponentially without discontinuity.

The moving average and exponential smoothing are effectively low-pass filters, filtering out high-frequency (or short-period) variations. Figure 3 shows the frequency domain properties of the two filters, calculated by taking Fourier transforms of the time-domain coefficients.

The moving average filter shows distinct side lobes. As the frequency increases (or period decreases) the filter swings back and forth between cutting out variations and letting them through. The exponential smoothing filter is much better behaved, with the filter amplitude decreasing monotonically with increasing frequency (or decreasing period).

Because of the smoother behaviour of exponential smoothing (as seen in Figures 2 and 3), the Continuous Stockpile Model System (CSMS) is designed to enable the mine planner to select material each 12-hour shift so as to bring the exponentially smoothed forecast grade back to target.

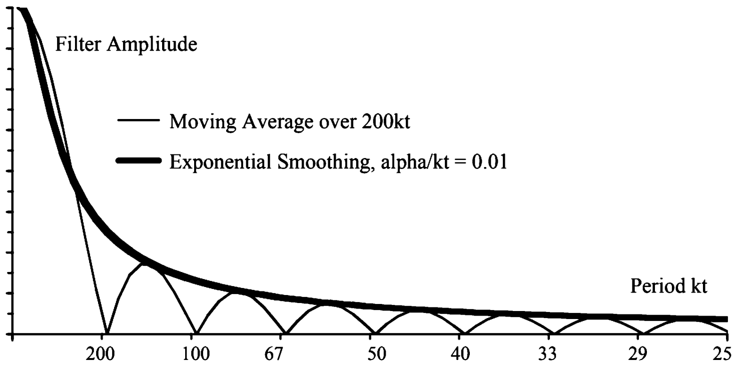

Figure 3: Moving average and exponential smoothing in the frequency domain

Constraints versus an Objective Function

The accepted policy had been to attempt to build stockpiles to within an acceptable tolerance "+/-t" of the target grade "T". If a stockpile had grade lying within tolerance on each mineral, then it was acceptable, otherwise it was considered unacceptable.

One problem with this approach is that it ignores measurement error: a measured grade lying just within tolerance may actually be outside tolerance, and vice versa. The acceptable/unacceptable discontinuity also makes for a jerky control system, and does not allow for trade-off between the four important mineral components.

For the reasons outlined above, it is preferable to include the grade targets and tolerances in the objective function, instead of treating as constraints. For each mineral component "i", we can define a non-dimensional stress as:

$$\text{Stress}[i] = (\text{Grade}[i] - \text{Target}[i])/\text{Tolerance}[i] \qquad (5)$$

The objective function is then to build stockpiles so as to minimise the Total Squared Stress:

$$\text{Total Squared Stress}[i] = \sum \text{Stress}^2[i] \qquad (6)$$

Figures 4 and 5 compare the constraint and objective function approaches. In Figure 4, where the tolerance is expressed as a

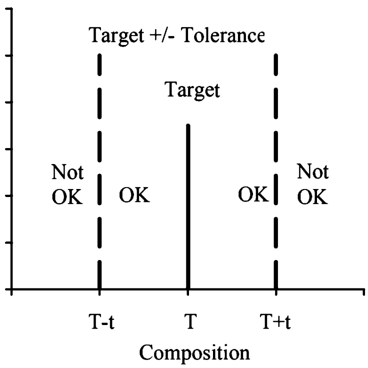

Figure 4: Tolerance as a Constraint

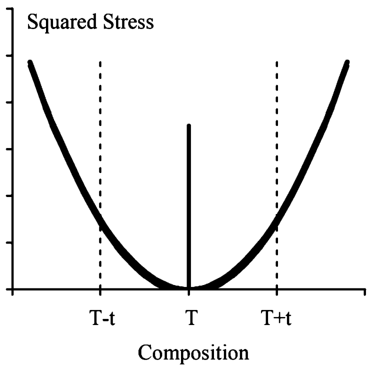

Figure 5: Stress as an Objective Function

constraint, anything in the range T-t to T+t is totally acceptable, and anything outside that range is totally unacceptable. In Figure 5, treating the degree of departure from target, relative to tolerance, as an objective function, there is no discontinuity, but increasing departure from target is increasingly undesirable.

Adjusting the Mine Forecasts

Let the target grade be $\underline{T}$. The material selected in the n^{th} shift should have forecast grade F_n, chosen so as to bring the exponentially smoothed grade back as close as possible to target (minimising the expected squared stress). Generally, assays are available for production up to two shifts prior to the planned shift, so a forecast must also be used for the previous $(n-1)^{th}$ shift (already mined) as well as for the n^{th} shift now being chosen.

The grades of the available ore sources for mining have to be estimated as a forecast. The forecasts are based on the mine estimates from exploration drilling of the deposit, adjusted to take account of the comparison between recent mine estimates of grade $\underline{M}$n and their subsequent product assays $\underline{P}$n (which are available for production up to the shift before last, i.e. $\underline{P}_{n-2}$).

We would like to minimise both systematic and random error in the forecast. If the mine estimates have recently "averaged" $\underline{M}$*n and the product assays have recently "averaged" $\underline{P}$*n, then $\underline{P}$*n-$\underline{M}$*n is a sensible estimate of the "average" systematic error. The "average" should be an appropriately weighted mean, giving more weight to recent experience. If too much weight is given to recent experience, then the estimated systematic error will be largely noise. If too little weight is given to recent experience, then the estimated systematic error will be too slow in responding to real changes. Exponential smoothing provides an appropriate method for constructing a weighted history of the systematic error. There is no reason why the appropriate smoothing constant (which we shall call $\beta 1/kt$) should be the same as that for emulating stockpiles ($\alpha 1/kt$). Consequently, we shall use the notation $\underline{P}^*n$ to denote exponential smoothing by $\beta 1/kt$, whereas $\underline{P}'n$ denoted exponential smoothing by α_1/kt.

For shift n, we are considering selecting ore with mine estimate composition $\underline{M}_n$. Product assays are available up to shift n-2. Correcting for systematic error, the adjusted forecast A_n would be estimated as:

$$\underline{A}n = \underline{M}n + \underline{P}^*n\text{-}2 - \underline{M}^*n\text{-}2 = \underline{P}^*n\text{-}2 + (\underline{M}n - \underline{M}^*_{n-2}) \qquad (7)$$

Equation (7) allows for systematic error, but not for random error. If $\underline{M}n$ is above average, then $\underline{P}n$ is likely to be above average, but by less than is $\underline{M}n$. If $\underline{M}n$ is below average, the $\underline{P}n$ is likely to be below average, but by less than is $\underline{M}_n$. This is a classic regression situation, and equation (7) can be modified to:

$$\underline{A}n = \underline{P}^*n\text{-}2 + r(\underline{M}n - \underline{M}^*n\text{-}2), \text{ where } 0 < r < 1 \qquad (8)$$

Equation (8) requires two parameters, the regression coefficient "r", and the smoothing constant b_1/kt. The values of the two parameters are chosen so as to maximise the reduction in error variance:

$$\text{Error Variance Reduction} = 1 - E[(\underline{A}n - \underline{P}n)2] / E[(\underline{M}n - \underline{P}n)2] \qquad (9)$$

Using the available historical data, adjusted forecasts were calculated for a range of values of the regression coefficient and the smoothing constant b_1/kt. Comparison of the adjusted forecasts with the corresponding product assays, as in equation (9) gave an estimate of the reduction in error variance.

Figures 6 and 7 show the reduction in error variance, as a function of the regression coefficient r, and of the smoothing constant β_1/kt, for each of the four control minerals.

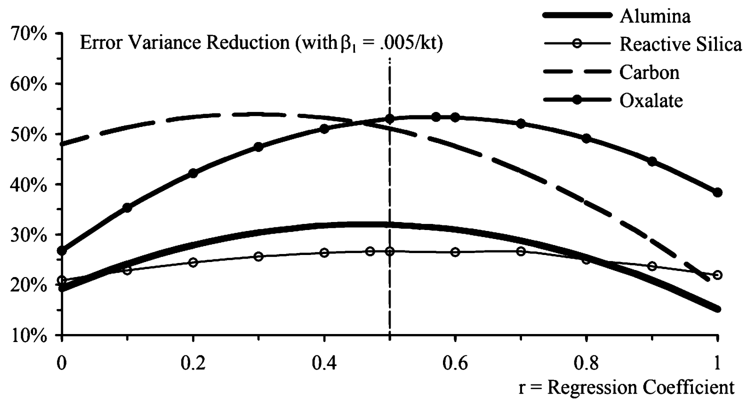

Figure 6: Error Variance Reduction - Sensitivity to "r"

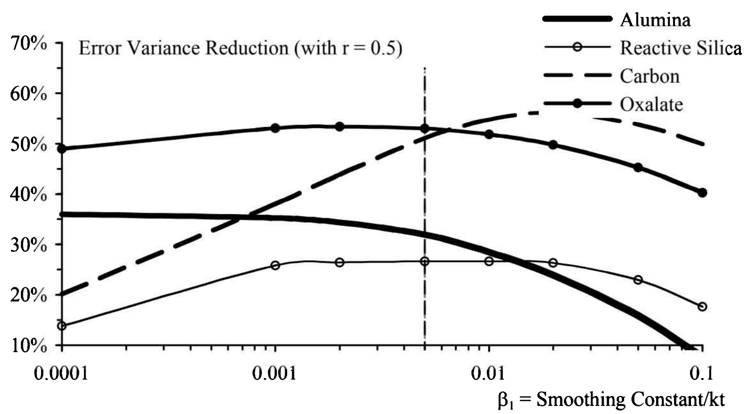

Figure 7: Error Variance Reduction - Sensitivity to "β_1"

Figure 6 shows that the reduction in error variance increases to a maximum and then decreases, as r is increased (while keeping β_1 constant). The optimum is not the same for each mineral, but an r of about 0.5 is a reasonable compromise.

Similarly, Figure 7 shows that the reduction in error variance generally increases to a maximum and then decreases as $\beta 1$ is increased (while keeping r constant). Again, the optimum is not the same for each mineral, but in the interests of a simple uniform model, a value 0.005/kt for $\beta 1$ is a reasonable compromise.

Selecting the Ore to Mine

At each shift n, a selection of ore must be selected for mining. With the Continuous Stockpile Management System, ore is selected so as to bring the (forecast) exponentially smoothed stockpile grade as close as possible to target.

When choosing ore of adjusted forecast adjusted grade $\underline{A}n$, we already know the product assay grade $\underline{P}n$ for period n-2, but must use the forecast $\underline{A}_{n-1}$ for the previous period n-1, since its assays will not yet be available.

We aim to select ore of forecast grade $\underline{A}_n$, such that:

$$\underline{T} = \alpha n\underline{A}n + (1-\alpha n)(\alpha n\text{-}1\underline{A}n\text{-}1 + (1-\alpha n\text{-}1)\underline{P}'_{n-2}) \qquad (10)$$

$$\underline{A}n = (\underline{T}(1-\alpha n)(\alpha n\text{-}1\underline{A}n\text{-}1+(1-\alpha n\text{-}1)\underline{P}'n\text{-}2))/\alpha n \qquad (11)$$

Usually, sufficient range of ore is not available for fully satisfying equation (11) in all four minerals, so the selection is done so as to minimise the Squared Stress of the departure from the target. The problem is essentially a quadratic programming problem, but can readily be achieved using the Solver™ facility of Excel™. For a description of a CSMS system successfully developed for an iron ore mine, see Kamperman, Howard & Everett (2002). The system described there was developed as an Excel™ workbook, controlled by menu driven VBA macros, using Solver for the optimisation. Very similar procedures could be used for bauxite ore selection.

Simulated Results

Data from fifteen months mining operation were analysed. The tonnage mined, mine estimate grades (from exploration drilling) and the final product grades were available for each 12-hour shift. Using the method described above, the adjusted forecasts for each 12-hour production were calculated.

Simulating Actual Production

The actual production experience for building 200kt stockpiles was simulated by taking the moving average of the production grade across 200kt of mined ore. This was done by taking a moving average across eleven 12-hour shifts.

Production in each 12-hour shift averaged 18.21kt. So the moving average across eleven 12-hour shifts corresponded to 200.3kt, with a standard deviation of 23.4kt.

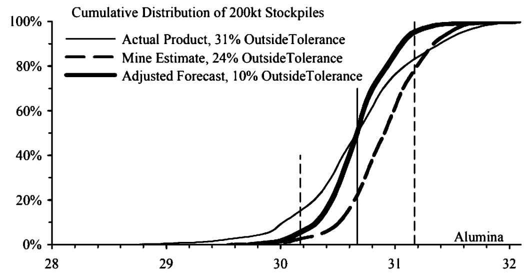

Figure 8: 200kt Stockpile Variability for Alumina

Selection of Ore with a CSMS Using Mine Forecasts

For the CSMS simulations, it is assumed that ore is selected for each 12-hour shift so as to bring the forecast smoothed composition back to target, as in equations (10) and (11).

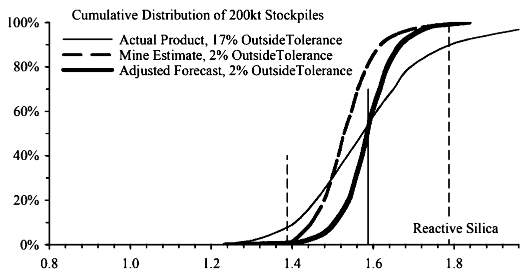

Figure 9: 200kt Stockpile Variability for Reactive Silica

Using the original mine forecasts (based upon exploration drilling), the simulation selected ore for each shift to bring the exponentially smoothed grade back to target. This forecast would of course turn out to have an error: the product assay grade was assumed to differ

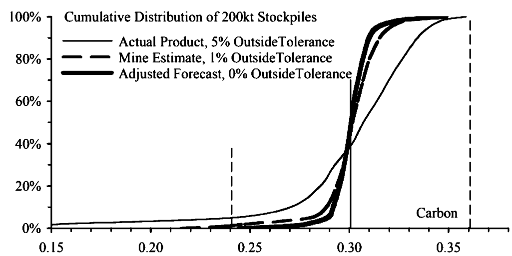

Figure 10: 200kt Stockpile Variability for Carbon

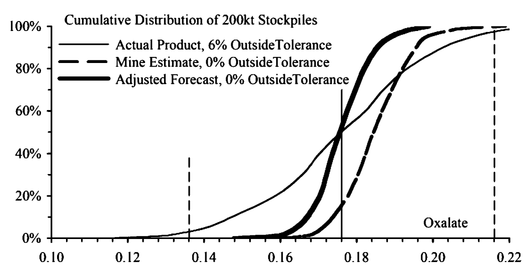

Figure 11: 200kt Stockpile Variability for Oxalate

from the mine estimate by the same amount as the actual product grade for that shift differed from the actual mine estimate.

Again, 200kt stockpiles were simulated, by taking the moving average of the simulated product grade, over eleven 12-hour shifts.

Selection of Ore with a CSMS Using Adjusted Forecasts

For this CSMS simulation, adjusted forecasts were used to select the ore to be mined each shift. The forecast adjustment was as shown in equation (8), using $r = 0.5$ and $\beta 1 = 0.005/\text{kt}$.

The forecast error was assumed to be the same as the difference between the product grade and the adjusted forecast grade for the same actual shift.

Again, 200kt stockpiles were simulated, by taking the moving average of the simulated product grade, over eleven 12-hour shifts.

The results of the three sets of simulations are graphed below, for alumina, residual silica, carbon and oxalate.

Comparing the Three Simulations

Figures 8 to 11 show comparisons of the three simulations for each of the four minerals of interest.

In Figure 8, the thin line shows the cumulative distribution of the alumina grade of actual stockpiles, built under the previous grade control procedures. About 18% of the completed stockpiles were below the tolerance, and a similar proportion above the tolerance limit, giving a total of 31% of completed stockpiles outside the tolerance range in alumina. If the Continuous Stockpile Management System (CSMS) had been adopted, using the mine estimates to select ore for mining, so as to restore the continuous stockpile grade to target, then only 24% of stockpiles would have been outside tolerance in the alumina grade, as shown by the thick broken line. If the CSMS had been used, with adjusted forecasts to guide ore selection, then the proportion of completed stockpiles outside tolerance would have been further reduced to only 10%.

Figures 9, 10 and 11 show similar results for each of the three contaminant minerals, reactive silica, carbon and oxalate.

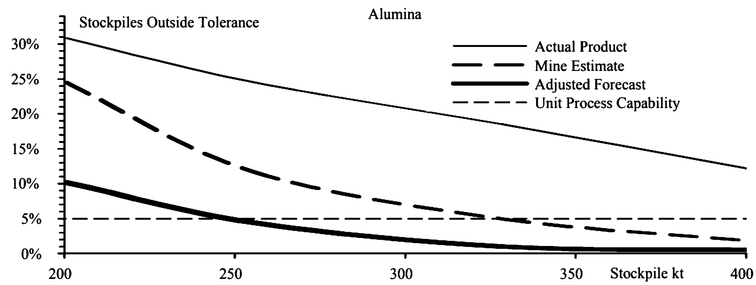

Figure 12: Effect of Stockpile Size for Alumina

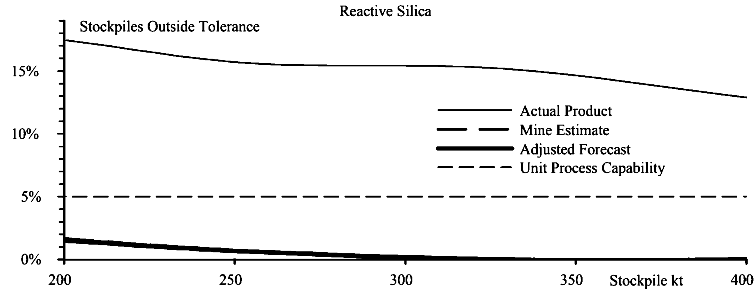

Figure 13: Effect of Stockpile Size for Reactive Silica

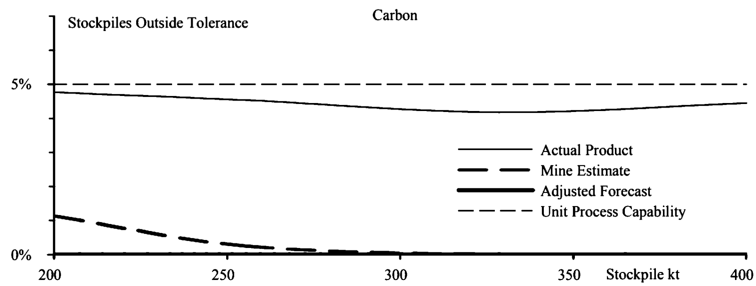

Figure 14: Effect of Stockpile Size for Carbon

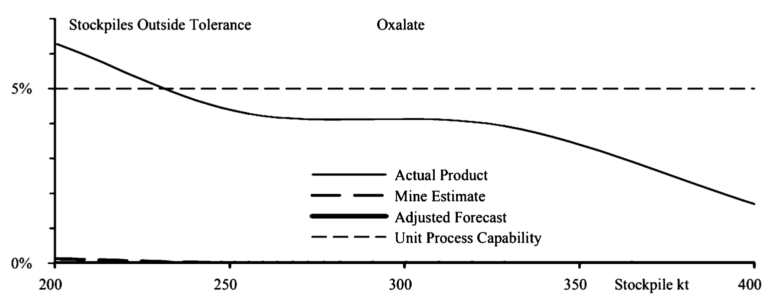

Figure 15: Effect of Stockpile Size for Oxalate

could have greatly reduced the stockpile variability. Using the adjusted forecasts in place of the mine estimates improves the system performance further.

Effect of Stockpile Size

Increasing the stockpile size will decrease the stockpile grade variability. If the ore grade had no serial correlation, then the decrease in stockpile variability would be proportional to the square root of the stockpile size, so quadrupling stockpile size would halve the stockpile grade standard deviation. However, ore grades have a positive serial correlation (high grades tend to be followed by high grades in the short term, and vice versa) so the decrease with stockpile size is actually slower.

Larger stockpile sizes were simulated, by taking moving averages over more than eleven shifts. Each shift averages 18.21 kt, so a stockpile size of 255 kt can be simulated by taking moving averages across fourteen shifts, a stockpile size of 310 kt by moving averages across 17 shifts, and so on.

Figures 12 to 15 plot the proportion of stockpiles against stockpile size. For the purposes of this paper, "Process capability" is defined as the tolerance range divided by the 95% confidence limit. With unit process capability, 5% of stockpiles lie outside tolerance, a reasonable operational goal.

In the Figures 12 to 15, simulations for the actual product are shown as thin solid lines. Simulations of the CSMS, with ore selection guided by mine estimates and by adjusted forecasts are shown by broken and by solid thick lines respectively.

Figures 12 and 13 show that increasing the stockpile size would not achieve unit process capability for alumina or for reactive silica, using the actual product generated by the previous ore selection procedure. For a CSMS with ore selected using adjusted forecasts, unit process capability for alumina could be achieved with a stockpile size of 250kt. For the three contaminating minerals, (reactive silica, carbon and oxalate, shown in Figures 13, 14 and 15 respectively) the CSMS would yield better than unit process capability even for the current 200kt stockpile size.

Results

Selection of ore to be mined for each 12-hour shift has to be based upon incomplete information, because the ore is not assayed until later, when it has been mined, transported, crushed and sampled. The ore selection decision must therefore be based upon inaccurate mine estimates, derived from previous exploration drilling of the area. This paper has shown how an exponentially smoothed comparison of previous mine estimates and their subsequent product assays provides information allowing the mine estimates to be converted to adjusted forecasts, correcting for systematic and random error.

Using these adjusted forecasts to select ore so as to bring the Continuous Stockpile grade back to target has the potential to greatly reduce the proportion of stockpiles outside tolerance. This improvement to the uniformity of the refinery feed grade can be used to improve the refinery performance, with considerable cost savings.

The described system can achieve cost savings by reducing the variability of feed grade to the refinery, where the bauxite ore is converted to alumina. Decreasing the feed variability increases the refinery's efficiency and reduces its operating costs. The CSMS method also removes the need for costly re-handing and blending of ore prior to it being delivered to the refinery.

Effective application of the CSMS does depend upon a sufficient range of available ore being available at each shift to allow a selection bringing the forecast composition back close to target. The current mine planning process appears to satisfy this requirement.

Genesis

It is of relevance to outline the history of this project, how it came to be started, its development and its deployment.

The author had over the previous ten years created a number of decision support systems for iron ore mining, and had been instrumental in developing and implementing the idea of a "Continuous Stockpile Management System" (Everett, 1996, 2001, 2007). This process approach has successfully replaced the previous "batch" stockpiling in many West Australian iron ore mines, and the author has over the years developed a fruitful working relationship with many iron ore mining practitioners.

Open-cut mining is a fairly fluid occupation, with staff frequently moving from one industry or company to another. As it happened, a couple of mining engineers who had previously worked in the iron ore industry, using my decision support systems, found themselves now working at a bauxite mine. Although the minerals of concern differ, the bauxite-mining objective is very analogous to that of iron ore mining, with the same need to generate a product having a consistent multidimensional composition vector. Finding their new environment at the bauxite mine was using ad hoc batch procedures, they realised that some of the techniques I had developed for iron ore decision control should be transferable to the bauxite industry. Accordingly, they contacted me in mid 2006, and we set about jointly establishing whether the methods developed for iron ore quality control could be adapted to the bauxite context.

The hardest and most important initial task was to convince other staff, unfamiliar with the iron ore industry developments. This was done by a series of presentations, showing the iron ore CSMS approach and demonstrating the analogy to bauxite mining, and some analyses and simulations using historical data to demonstrate the improvement in quality control that could be expected.

The initial design was accepted in principal in late 2006, but then hung fire until a budget was approved in July 2007. The system was then constructed over the following six months, with frequent iterations to and from the potential users. Because the system was implemented in Excel, it was easy for the users to try it out as it was being constructed. I took the approach of keeping the system as simple as possible, reluctantly adding "bells and whistles" in response to explicit user requests. This way, a sense of ownership was developed in the users, and their implicit knowledge was tapped and incorporated.

The system was deployed for daily use in early 2008, with a few minor modifications being incorporated over the first six months of use. Apparently, it is still being used and fulfilling the client's needs.

In retrospect, the successful outcome of the project owes much to the transfer of appropriate techniques from an analogous industry. This transfer was greatly facilitated by the migration of staff between the industries, carrying knowledge of the techniques and of my prior experience. In particular, one of the staff members who I had previously worked with in the iron ore industry provided that essential ingredient: the internal champion and mentor of the project.

Conclusions

Relating the project to the methodology in Chapter 2 seemed a bit like rewriting history, since the work was carried out in ignorance of his excellent conceptualisation, but was based on experience and "muddling through".

However there are obvious analogies that the reader can see between the work described here and Eli Cohen's methodology. Having developed information systems with industry over many years, I have found some useful guidelines that I shall try to spell out. In many ways they represent applications of the Cohen evolutionary approach, and I would use it as a reason to avoid excessive theorising about the nature of information systems. I would be quite happy with a simple definition of information systems as being "systems that inform".

In my experience, successful information systems grow from small beginnings in an evolutionary response to user demands. It is best to start by building a simple support system, for an identified well-defined decision problem. Almost invariably users then come back asking for further features to be added, and, as the embedded information evolves, they ask for graphs and other outputs of source and derived material. The developer's task is reluctantly to respond to these requests, and thus an informing system evolves.

I also keep stressing some overlapping clichés when dealing with client users:

1) You have to spend time with them "finding answers to the questions you didn't know to ask".

2) The users have "domain knowledge" the consultant lacks, though they may have difficulty formulating it.

3) The users have to keep ownership: Ideally they should feel that they designed the system, not the consultant.

Even if (3) is not true, the users should believe it is, so that they want the system to work.

The user client needs to be provided with a "fishing line not a fish". The consultant should not just deliver a package and walk away, but jointly with the client develop an understanding of the decision system: this mutual learning is a necessary prerequisite and just as valuable as the informing system itself.

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Chapter 16

Information Politics and Information Culture: A Case Study

Bob Travica

Introduction

The purpose of this chapter is to present concepts of information politics (infopolitics, for short) and information culture (infoculture) that support the principle of interdisciplinary research promoted by informing science (Cohen, 1999). The concepts of infoculture and infopolitics come from the Information View of Organization (Travica, 2003, 2005). Due to its similarities with informing science, this framework is also called Informing View of Organization (Travica, 2006). The acronym "IVO" signifies either term in the further discussion.

A fundamental assumption behind IVO is that classical views of organizations, such as cultural, political, and structural one, need to be applied directly to information and information technology (IT). Information and IT are central concepts in the framework, assumed to be informing agents that make a significant impact in organizations. Information is conceptualized broadly to mean data, meaning, knowledge, and wisdom. (In further discussion, the singular term "information" refers to all these different forms; when the phrase "information and knowledge" is used, "information" refers to "meaning"). IT is also conceived more broadly, referring to any means of creating and manipulating information, both electronic and pre-electronic. IVO assumes that information and IT have a prominent cultural, political, process, and structural existence, which complements, influences, and is influenced by organizational culture, organizational politics, processes, and organizational structure. Figure 1 depicts the IVO framework.

Table 1 contains brief definitions of the main IVO concepts. Two of these that are discussed in this chapter—infoculture and infopolitics—will be discussed in detail below.

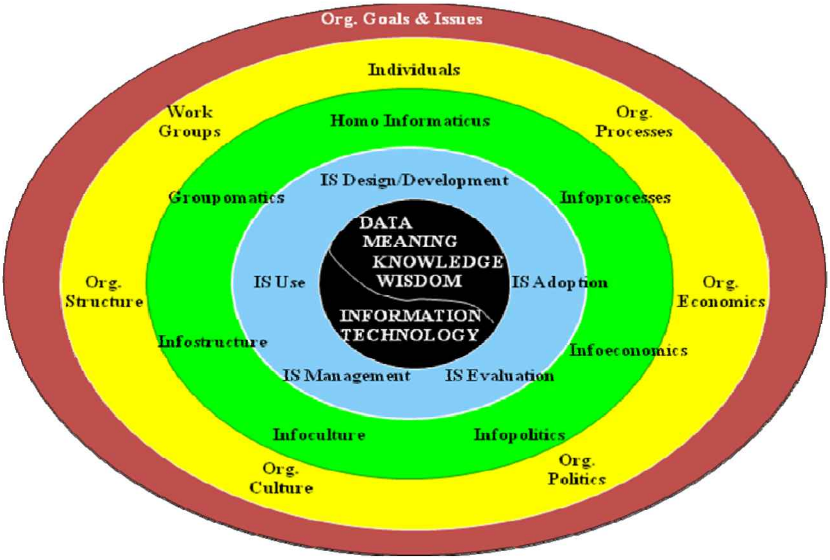

Figure 1: The Framework of IVO

As depicted in Figure 1, IVO places information and IT artifacts at the nexus of the organization. These are related in the concept of information system (IS), which refers to an informing purpose-focused whole that consists of data (the simplest form of information), IT, and procedures (both automated and manual). This concept of IS is accepted by many in the IS field and is particularly used in the discipline of IS analysis and design. This IS concept approximates Cohen's (1999) "delivery system" that intermediates between "sender" (informer, information provider) and "receiver" (client, information user). The next orbit in Figure 1 exhibits the standard IS-related themes of research. IT, in formation and IS are a function of organizational goals and issues (questions demanding attention, challenges, and problems), which lie in the outermost orbit of IVO. Information and IT are tied in a yin-yang-like relationship. Information gives purpose to organizational IT, while being molded by it; IT makes a difference in information (medium is a message), while being in service of information. Furthermore, data and IT are part of an IS, and the user of IS uses these to create a meaning situated in a task and organizational context. Knowledge in its various forms is engaged in the process of using IS as both the antecedent and a potential consequence. It should be noted that cooperation between information

Table 1: Main Concepts in IVO

IVO Topic	Focus / Definition
Homoinformaticus	Individual cognition, individuals as creators and users of information and IS.
Groupomatics (Group Informatics)	Group cognition, decision making, work and supporting IS
Infostructure	Stable patterns of relationships between information segments and the arrangement of IT that complement social structure.
Infoprocesses	Interrelated information activities that altogether deliver an outcome to a customer.
Infoculture	Beliefs, behaviors and artifacts that are related to information and IT (organizational informing agents).
Infopolitics	Power, agendas and fight/flight behaviors related to organizational informing agents.
Infoeconomics	Costs, benefits, and organizational performance associated with organizational informing agents.
IS Life Cycle Issues	Management, Design, Adoption, Use, and Evaluation of IS by different occupational groups.

and IT is not axiomatic. Competition between the two can arise as well. The character of this relationship is an empirical question that is raised with every new IS or a significant change of an existing IS. Figure 1 further shows that topics of IS research and of organization theory intersect, thus creating infoculture, infopolitics, and other dimensions that signify a distinctive contribution of IVO to research. The implication is that IVO gives an IS slant to "views of organization," while IS theory acquires a firmer anchoring in organization theory.

While borrowing liberally from organization theory, the home of IVO is in the IS field. IVO brings IS phenomena to the forefront and demonstrates that these are inextricably coupled with organizational aspects. In addition, IVO intends to introduce a unified vocabulary that would clearly indicate links between organization theory and IS theory. The most fundamental purpose of IVO is to increase a crosspollination between the two theoretical fields. Such a purpose has been presaged in the premises of informing science (see Cohen, 1999), recognized by influential scholars in both fields (e.g., Orlikowski and Barley, 2001), and made the *leit motiv* in current discussions about the evolution and destiny of the IS field. A better academic crosspollination is expected to raise the value of both fields for practical organizing and managing. In particular, shifting attention to information and IT as the phenomena that are central to organizational politics and culture may have significant implications in the development and performance of real-world organizations.

The text in the reminder of the chapter is organized as follows. Infopolitics and infoculture are defined and the relevant literature is reviewed. Subsequently, a case study is presented, which as a pilot test for these IVO concepts. Finally, findings of the study are summarized and mapped back into the relevant literature and the IVO perspective, and implications for research are outlined.

Literature Review

This section discuses the literature that supports our conceptualizing of infopolitics and infoculture. We draw on both IS theory and organization theory. Direct conceptualizations of infopolitics and infoculture are rare in the literature, and we will have to resort to a creative deconstruction of the tangent texts in order to detect valuable content. In the case of directly comparable concepts, we will examine them and point out to the usable content and modifications that are necessitated by IVO.

The Concept of Infopolitics

We define infopolitics in terms of power, agendas, and fights/flights that are related to organizational information and IT. This relationship implies that information and IT can influence the aspects of infopolitics (e.g., control over data and IT is a source of power) as well as being influenced buy it (e.g., the agenda of a certain party determines design and use of data and IT).

Sitting at the nexus of contemporary organizations, information and IT constitute high political stakes. This premise has support in both organizational theory and IS theory. Students of organizations have maintained for long that professional knowledge can be used as a source of power (Crozier, 1964; Mintzberg, 1979; Pfeffer, 1981). By having some special knowledge that others consider a resource, the knowledge holder can influence thought and behavior of others. Feldman and March (1981) suggested that information could support power in even subtler ways. Managers that accumulate periodic reports on their desks implicitly signal their place in organizational hierarchy. Therefore, mere possession of organized data, rather than using it in decision making, may be an aspect of power. Organizational scholars have also addressed technology in conjunction with information and power. While Crozier (1964) associated the power basis with know-how of maintaining manufacturing technology, Barley (1986, 1990) shifted attention to know-how of modern IT used for medical purposes. He found that knowledge of using computer tomography and interpreting its output made technicians more powerful than radiologists, who had a power advantage while X-ray technology was in fashion. Beniger (1986) has provided a compelling argument that any IT is a technology of control. His accounts of how the telegraph was used to control railroad traffic can be extended smoothly to today's cellular (mobile) phone, which, in principle, makes the phone owner a subject and object of control, irrespective of space. In all these examples, IT and knowledge of using it contributes to creating a basis of power. The literature on new organizational forms has also touched on power issues in relation to modern IT and information (e.g., Clegg, 1990; Goldman, Nagel, & Preiss, 1995; Mintzberg, 1979).

IS theory has also addressed issues of organizational politics. Danziger Dutton, Kling, & Kraemer (1982) studied consequences of deploying computers in American local government organizations, and published results in a report entitled "politics." Upon parting from the paper trail, local government organizations from various domains (e.g., financial and personnel administration, police, procurement, courts, and utilities) used computers for record keeping, analysis, and decision making. The authors found that IT supported speed, direction, content and pattern of information flows in such a way that the previously dominant individuals and groups simply reclaimed their positions. Danziger and colleagues termed this outcome "automation of bias," while putting forward their proposition of IT being a "malleable technology" that is capable of serving various interests. This study is important for hinting on what can be considered infopolitical dimensions—the speed, direction, content and pattern of information flows. The notions of control patterns automation and of malleable technology are also helpful.

Zuboff (1984) also identified the phenomenon of reconfirming political positions with new IT and corresponding information management, with the stipulation that power shifts are possible as well. In her highly acclaimed study, which contains "power" in its title, Zuboff (1984) found that there could be two opposite political outcomes from deploying new digital IT in manufacturing and service industries. When adoption of IT coincides with opportunities for organizational change, workers could become empowered and enriched by new skills, and a more meaningful work could result. Zuboff calls this outcome informatization. When change opportunities are lacking, IT coincides with a further deskilling of workers and reconfirming of old power distributions—the outcome termed automation. Zuboff's study is important for pointing to different political agendas coalescing around new IT. In the discussion further below, we will use these examples for conceptualizing agendas of infopolitics. Also, Zuboff's investigation illuminates dialectical aspects of organizational politics related to IT and information. We reflect these aspects in the infopolitical dimensions of fight and flight.

The themes of agendas and fight/flight dialectics in infopolitics apply to the system development process as well. Although working within their specific theoretical frameworks, we believe that a number of researchers have provided useful leads. In particular, various streams within Scandinavian IS research made the theme of political dialectics in the IS development process central to research (see Greenbaum & Kyng, 1991; Iivari & Lyytinen, 1999). Orlikowski (1992) also identified agendas and fight/flight behaviors in confrontations between developers of CASE software and management, and Hanseth, Ciborra, & Braa (2001) detected these phenomena in tensions between corporate units and a strategy of changing organization through an ERP system. Orlikowski (1992) studied ethnographically how CASE software was developed in a large software firm. The software was supposed to improve the productivity in developing IS for the firm's clients. This was done by embedding the firms' IS development methodology in the CASE software, which applied down to specific tasks (e.g., the method of developing user interface). The result of using this software was standardization of work. Orlikowski argues that this can be viewed as an unobtrusive way of controlling the content and coordination in the process of developing IS. However, when system developers felt as being unreasonably constrained by the mandated procedures the CASE software supported, they would resist. For example, they bypassed some functions of the software or even altered them. These findings confirm again that IT is closely associated with power since it can be an extended hand of controlling work consistently with Beniger's (1986) argument. In addition, one can see how system developers fly together in order to fight the imposed organization of work (the IS development methodlogy) and the management behind it. The managers' agreement to enforce the development methodlogy via the CASE software and thus exercise control over the content and speed of work can also be seen in terms of IT-related flight and fight.

Hanseth and associates (2001) contribute to understanding the same phenomena in relation to ERP systems. These systems typically lead to centralizing information management with paramount political implications: individuals and groups that obtain access to centralized information can enlarge their power basis. Hanseth and associates acknowledge this outcome, while suggesting that the political process may not be straightforward since the centralization force can provoke its counterpart. This indeed happened in the organization the authors studied, Norsk Hydro. This has been a corporation with a global presence that embarked on cross-divisional implementation of an ERP system. The management at the headquarters championed the system, with the goals of achieving a tighter integration and control of the corporation. However, as the project evolved, a number of user groups grew up at dispersed organizational units. In spite of the initial management intention to build one coherent, common system, the implementation process diverged into developing many variants of the system customized to local needs. An implication is that work processes built into the system were not uniformly modeled across organizational units. Another finding is that the system implementation process initially created a momentum for organizational change. Once rolled out, however, the complexity of the system, coupled with maintenance costs, became a hindrance for further changing of organization. From the perspective of infopolitics, centralizing information management is the antecedent to centralizing power. As this case shows, the champion of the ERP system was the upper management, which hoped to seize more power. This is consistent with organization theory: Mintzberg (1979) equated a "strategic apex" of organization with a "pull to centralize." We can add that the centralization pull finds a strong leverage in ERP systems. However, the study also shows that the dispersed organizational units have resisted and managed to keep some autonomy in terms of both system and organizational design. Variations in design of the enterprise system and the thereby induced variation in work procedures were their leverage for saving some political autonomy. This study can help grasp fights in the domain of infopolitics triggered by centralizing information.

Computer meditated communication (CMC) also interacts with organizational politics in various modalities. Groups can evolve around shared interests, using electronic links for self-maintaining exchanges and for advancing their political agendas (Hiltz & Turoff, 1978; Spears & Lea, 1994; Sproul & Kiesler, 1991; Zuboff, 1984). These political agendas may lead to political fights that result in power changes. A redistribution of power in the CMC context may also come in milder forms, where the intervening factor is argument rather than fight between juxtaposed camps. In an analysis of email communication that transpired within a software development project, Orlikowski and Yates (1994) found that email was used for democratic dialogue, which was occasionally punctuated by balloting acts. As opposed to verbal or paper-based dialogue, electronic dialogue had a capability of chaining the content, thus creating lines of conversation. These led to several ballots. Decisions derived from the ballots were just partially based on the majority vote. Some gave advantage to authority, and so reproduced the old power structure; others favored knowledge, thus favoring knowledge-based power over authority; and yet other decisions were influenced by a sheer persuasiveness of argument, creating even more of a power shift.

Even more tacit political changes can take place in the CMC context when agendas are not clearly articulated and power gains are mapped into the realm of perception. For example, Travica (1999) has found that the usage of IT in small offices of the American public accounting industry is positively correlated with professionals' perception of a decreased centralization—therefore, a greater professionals' autonomy. Still, the hierarchy was invariant and indifferent of IT usage. Therefore, management control was formally intact, although professionals did not perceive it as such.

Markus's (1983) field study of an accounting system in a chemical company is paradigmatic for many themes of infopolitics discussed above. She studied organizational implications of deploying a Financial Information System (FIS). Design of the FIS and changes in control over accounting information created a battleground between divisional and corporate accountants. The former group performed managerial accounting (processing real time information for management and forecasting purposes), while the later group did financial accounting (processing historical information for the purposes of external reporting). Corporate accounting was a new function, placed between corporate management, which it served, and the company's divisions. The corporate accounting function initiated the FIS and defined system requirements on its own. A significant change the FIS introduced was that it redirected the flow of information from the divisional to corporate accountants. Divisional accountants could no longer summarize transactional raw data and send just the summaries to the corporate accountants. The FIS collected all transaction data in a central database, which was under the control of corporate accountants. They could query the data at any time and, on that basis, assess performance of divisions. The FIS also imposed that profit reports, which were in the domain of managerial accounting, had to be based on individual products rather than on aggregate data as used to be the case. Feeling to be at loss, divisional accountants tried to undermine the FIS and fought for saving their old system, which produced aggregate reports. This study suggests that organizational actors stake their agendas on new IS, and compete (fight) for controlling it. Winners gain information-based power, which, in turn, underpins their social power. The study also reinforces the hint on infopolitical aspects that Danziger and colleagues (1982) introduced: the speed, direction, content and pattern of information flows pertaining to a particular IS have to do with power distribution and other political aspects that evolve from this IS.

There have been attempts of categorizing organizational designs in relation to information (Boisot, 1987, 1998; Davenport & Prusak, 1997). Boisot (1987) derived different designs directly from two properties of information—codification and diffusion. Codification can be understood in terms of a transformation of visceral information into some communication code, formalization, compression, and classification (e.g., highly codified information is patent, while its opposite is tacit knowledge). Diffusion refers to the percentage of a population that a certain piece of information reaches. Ideas of distribution, availability, accessibility, and sharing can help understand diffusion (e.g., information on the Internet is more diffused than patent information). According to Boisot (ibid.), a clan is based on information that is low on codification and high on diffusion within the clan (not in the broader organization in which a clan as a group resides). On the contrary, bureaucracy thrives on information that is both more codified and diffused. Typologies are important for making sense of modalities of infopolitics that may be found in organizations.

In summary, in this section we discussed both IS and organizational literature that is instrumental in understanding our concept of infopolitics. This literature makes a connection between power on one side, and IT and information (in the broader sense) on the other. The literature also points to different aspects of infopolitics that are of our interest— power, agendas, and fight/flight in behavior and thought concerning information and IT. The discussion will now turn to the literature relevant for understanding infoculture.

Concept of Infoculture

We define infoculture in terms of stable beliefs (assumptions, values, norms, attitudes) and behaviors (work practices, rituals, social dramas, and communication) that refer to organizational information and IT. Infoculture is the part of organizational culture that evolves around information and IT. This means that information and IT can influence the aspects of infoculture (e.g., innovation in IT and information could require a change in deep-set beliefs or values on how things should be done) as well being influenced by infoculture (e.g., existing cultural values can determine the scope, speed and way of adopting a new IS). Note that our concept of culture includes both the mental and behavioral components, thus reconciling opposed ontologies (cf. Jaques 1952; Schein, 1991). We differentiate between the particular mental artifacts listed above based on the metric of stability—stability decreases from assumption toward attitude (see Hatch, 1997). Work practices refer to accustomed ways of working; rituals refer to acting out of the purpose of reinforcing; social dramas are rituals that sentence unacceptable behaviors; and communication behaviors imply communication content, channels, and language.

Taking on the lenses of infoculture, one can easily see that information and IT shape a considerable part of culture in any organization. For example, law firms and banks maintain strict norms aiming at securing the confidentiality of client data, and carry out corresponding work practices and rituals. Innovativeness and production of new knowledge have been raised to a level of cult at organizations like 3M and Microsoft. The Internet, as a rich technological and information context, features in stories explaining the advent of organizations. An example is MediPlan, a large international Internet-based pharmacy in Canada that allegedly was conceived when one of its founders realized that his selling of cheaper anti-smoking drugs to Americans on eBay could be grown into a full-fledged pharmacy business. Thus, norms, values, stories and, other elements of organizational culture that feature various kinds of IT and information are easy to pinpoint in these examples. This is what we mean by infoculture.

The leads to our concept of infoculture can be found in organizational and IS literature. Most of these are tentative, which means that the authors did not have infoculture in mind when they produced their studies. But there are also two cognate conceptualizations. Davenport and Prusak (1997) have defined information culture in terms of "a pattern of behaviors and attitudes that express an organization's orientation toward information" (p. 84). An example of infocultural attitudes is preferences for facts or rumors; examples of infocultural behavior include information sharing and preferences for types of communication channel, such as face-to-face vs. email. The authors distinguish between information culture pertaining to the group and organizational level and information behaviors that are demonstrated at the individual level (e.g., searching for information and using it) (pp. 84, 87). Bressand and Distler (1995) have used a concept of "infoculture" in the context of social networks. According to these authors, infoculture contains: "shared objectives and mutual expectations" that make a basis on which network members can agree on joint projects and mobilization of network resources; "rules that govern changes of rules;" and "the background knowledge" that actors take for granted and enact in their daily use of the network (cited in Ciborra, 1996, p. 122). Both these concepts are valuable for our conceptualizing of infoculture. However, we expand Davenport and Prusak's concept to include IT, and we avoid the ambiguity of the generalist cultural approach in Bressand and Distler's concept by focusing clearly on information and IT.

Deal and Kennedy (1999), prominent researchers of organizational culture, have provided a remarkable argument about the impact of computers on contemporary organizational cultures. While the authors give some credit to computers, their real focus is on what they believe are undesirable consequences of intensive use of this technology: "pluses are offset by diminished social interaction with one's peers and a sterile interface with a computer rather than a supervisor" (Deal & Kennedy, 1999, p. 148). For instance, rituals that used to be social are now machine-timed and dictated; face-to-face communication is more often than not replaced by impersonal electronic exchange; and old organizational cultures that fed on personal contact are replaced by new cultures of "computer-mediated life that distances people and finds heroes in the whiz kids who can fix software glitches or the computer system itself." The problem with computers, assert the actors, is that they are rarely used for reinforcing core cultural messages. Instead, computers have created new cultures of isolation and contributed to modern corporate maladies beside other causes, such as shareholder value and outsourcing. The interesting phenomenon Deal and Kennedy point to is that the primary effect of computers is to distance people. The literature on computer mediated communication lends some support to this claim. While the authors' interpretation of the distancing effect is value-laden, it corroborates our proposition that electronic IT has become a central cultural phenomenon in organizations.

Orlikowski and Gash (1994) used the term "technological frames" to refer to the way organization members make sense of and assign meaning to organizational artifacts and to assumptions, knowledge, and expectations expressed symbolically through language, visual images, metaphors and stories (p. 176). The authors studied an organization that was implementing groupware on a large scale. They identified two different sets or values and assumptions in this organization. One characterized the IS department (technologists) and the other pertained to the business core of the organization (users). The technologists maintained the values that praised technical indicators of work, believed that the new IT could change the firm, and assumed the users were typically ignorant about IT and that "they would come if the system was built." In contrast, the users valued business criteria of performance (e.g., hourly charging rate was the main unit of measurement), and could not associate the new IT with performance requirements. Information rather than IT was the key in their view, and it had to be accurate, secure and of a certain quality. Apparently, this study provides evidence on infoculture in the form of assumptions and values related to organizational IT and information. Another contribution to our concept of infoculture is in putting forward the postmodernist assumption that organizational culture can be fragmented (Kunda, 1992; Martin, 1992).

Another pointer to the phenomenon of infoculture is in Orlikowski's (1996) study of a software company's help desk, which used new database and communication systems. From the IVO perspective, the most interesting finding is that a whole corpus of new cultural artifacts had emerged in this organizational unit. For example, a value of good documenting of the problem solving process had surfaced. Then, the grapevine began relaying a dramatic story, which portrayed a frustrated user of the problem solving documentation that experienced a shock realizing that he was the author of the poor document. This story apparently reinforced the value of doing the documenting job well. A new norm prescribed the language used for documenting purposes: it had to be "professional and diplomatic." A part of new cultural legitimacy was that the authorship was considered to be a seal of quality. This norm implied that professional should strive to have their names dissociated from a poor documenting work and strive to become heroes of documenting. This logic brought the new culture reasoning to square one—"do document well!" Obviously, all these cultural innovations coincided with new IS. What may be less apparent is that they all referenced a common larger assumption: new knowledge created through solving customers' problems had to be preserved as a valuable resource. Therefore, we can see that information and IT are the source and sink of these innovations, and this fact gives them the character of infoculture. This study also suggests that infocultural changes may occur opportunistically rather than intentionally.

As in the case of infopolitics, ERP systems could be turbines of infoculture changes as well. Sarker and Lee (2000) found that the organization they studied had to change its "dysfunctional culture" in the course of implementing a large-scale enterprise system. Before the implementation, a culture set in characterized by "a sea of paperwork," a lack of trust, inefficient processes, and inadequate technological infrastructure (p. 419). Departments tolerated ambiguity surrounding the status of orders, and production and engineering departments could not get in agreement about scheduling. The former would routinely set production deadlines without asking the latter, and the latter would routinely resist. This culture of ambiguity and dysfunctional scheduling was attacked in preparations for the ERP system. Leadership, open communication, and an effective implementation team interacted in the process that led to success. Finally, practices of more open inter-departmental communication emerged along with coordinated scheduling as artifacts of a revamped organizational culture. Since infoculture is the part of organizational culture that evolves around IT and information, the important implication of this study is that ERP systems can trigger a radical transformation of infoculture. In addition, the study has outlined several characteristics that can be considered dimensions of infoculture—the proportion of paperwork vs. digital processing, the match between technological infrastructure and process efficiency needs, and properties of inter-departmental communication and coordination.

In summary, this section defined infoculture and discussed relevant organizational and IS literature. This literature has provided evidence and theorizing on various cultural artifacts that have to do with information and IT—assumptions, values, norms, stories, work practices, and rituals. Links between these and our conceptualization of infoculture have been outlined.

Methodology

Our empirical investigation of infopolitics and infoculture used the research design of case study (Hunter, 2004; Lee, 1989; Yin, 2003). It was a single organization longitudinal study, spread over 25 months (summer 2001-fall 2003). The organization investigated was a venue of large festival in Canada code-named the Folklandia Pavilion (or just the Pavilion), which has exhibited characteristics of a voluntary establishment and small businesses. Epistemologically, the study belongs to the interpretivist inquiry (Baskerville & Myers, 2004; Klein & Myers, 1999). Most of the works cited in the literature review above belong to this inquiry (Deal & Kennedy, 1999; Hanseth et al., 2001; Markus, 1983; Orlikowski, 1992, 1996; Orlikowski & Gash 1994; Orlikowski & Yates, 1994; Sarker & Lee, 2000; Zuboff, 1984).

Data Collection

For collecting data, a triangulated methodology was used that consisted of ethnography, interviewing, and document analysis. The ethnographic method drew on prolonged field observation and participation in activities and events in the organization studied. Ethnographic method originated in anthropology and have been used to a limited extent in IS research (e.g., Orlikowski, 1992; Suchman, 1987). The contemporary use of ethnography has somewhat deviated from the traditional model in which the researcher was supposed to be a neutral observer. Instead, the researcher is allowed to let his/her hidden self surface through action in the field and the cognitive makeup s/he brings into research—knowledge, beliefs, philosophical orientations, and emotions (Tedlock, 2000). The rationale is that social science deals with phenomena that are intersubjective in character, and, therefore, the researcher becomes yet another subject involved in the social context that learns not only by observing but also by interacting with others (Tedlock, 2000: 471; see also Baskerville & Myers, 2004, p. 332). The ethnographic method deployed in the present study enabled the researcher to have ready access to dozens of organizational members and experience actual organizational life. This data collection resulted in a journal, which contained observations, communications, and research design details (questions and hypotheses for research, incrementally developing findings, ideas for coding, etc.).

Interviewing was another method of data collection. The interview transcripts contain 82 entries related to the subjects interviewed—organizational members and external actors. Interviewing was performed in various modalities—from a short/structured to longer/semi-structured one. The third data collection method was document analysis. It was applied to various records on the organization's activities, meetings, finances, and performance. Furthermore, a database was developed in the course of study in an effort to create a chain of evidence linking the research question with methods, data, and this final report (Yin, 2003). The database contains paper and electronic documents on the preparations of the Pavilion and its operations during the festival days, archival documents, interview data, the journal, media clippings, coding schemes, tabulations of the categories coded, spreadsheets with financial data and calculations, email folders of certain organizational members for 2002 and 2003, and some other auxiliary information.

The case study intended to answer the following research question: *What are the aspects of infopolitics and infoculture in the organization under study, and how do they relate to other organizational aspects and organizational performance?* In accord with interpretivist field research, this research question was shaped in the course of the study (more discussion below).

The case data were analyzed in the course of study as well as after finishing the field investigation. During investigation, data analysis relied on the iterative process discussed below (see Figure 2). In a nutshell, once a focal construct of observation, interviewing, and document analysis was defined (e.g., a particular ritual of infoculture), a working hypothesis would be set and search for data followed. The definition of the construct was used to derive keywords to be used as a "sifter" for coding the data: Identified instances of a construct would be saved in the appropriate rubric, and potential useful data would be marked for a revisit in the future. Electronic tools assisted the process. More often than not, it happened that a single process would not end up with a finding as the researcher's attention was called to some emergent event or because relevant data were missing. The coding of all the data was revisited and finalized after the field investigation was closed. Another method used both during the investigation and afterwards was to have external readers comment on draft findings. These readers were some of the key organizational actors, and the drafts were write-ups of findings that would jell up in the process of research.

Process of Interpretivist Inquiry

The initial intention was just to learn about the internal organization and information practices and technologies in the Folklandia Pavilion. Then, as the study progressed, attention was focused on issues of infoculture. A trigger for the shift came at the very start, although it did not shape the research question right away. The person responsible for getting the researcher into the organization (the Informant) commented on difficulties in preparations of the Pavilion for a new Festival year:

> I feel as if we have to discover the hole on the flowerpot every year anew. Every time we start the preparations, we have to go through pains of shaking up our memories, wondering what we did the last year, how we did it, what happened, why we didn't do things differently... We learn and then we forget. Not very smart, eh?

The commentary above clearly indicated a possibility that knowledge management or records keeping methods were causing the trouble. A metaphor of "organizational amnesia" imposed itself as the guide at that point of investigation. We hypothesized that work manuals could have been deficient or inaccessible; documentation on problem solving could have been poor, as dramatically happened in Orlikowski's (1996) case. If access to information was a problem, some IT-related aspects could have been responsible (design issues, availability of IT, impact of IT on organization of data). The interesting fact was that nobody could tell us anything useful for explaining the "organizational amnesia." The people would just shrug their shoulders, or occasionally utter: "That's how the things have always been around here." We thought that tradition could have been a vague, general cause of "organizational amnesia," and if so, information and IT problems were related to it. Invoking the concept of infoculture became a sensible option at that point, and "infoculture" was brought into the research question. Then, we learned that the organization was low tech, primarily based on paper trail. We concentrated on accessing the organization's memory—the documentation on work procedures and problem solving, and paper records that tracked financial aspects.

Attempts to access organizational memory brought us, for the first time, before a wall. Part of the organizational membership knew nothing about this and believed that only a certain "privileged group" had a hold of the information in question. This "privileged group" consisted of seasoned volunteers that participated in the Folk Festival for many years. Some of the group members were buttoned up; others were kinder and promised help in accessing the requested information; and yet others asserted that all work manuals they ever needed were "in their heads." It took about four months to establish that a division between the "privileged group" and others really existed.

This preliminary finding suggested that part of challenges the Pavilion was facing had to do with organizational politics. Therefore, organizational politics became part of the research question. As the study progressed, the idea gradually crystallized that information politics could play a major role in the organization studied.

The last part of the study's research question asks about relationships of infoculture and infopolitics with other organizational aspects and organizational performance. This part was formulated at about the end of the first year of investigation. While the effort was concentrated on discovering causes of "organizational amnesia," the researcher also learned that the financial performance of the Folklandia Pavilion had usually been sub-optimal in comparison to similar pavilions participating at the Folks Festival. This elicited the idea to expand the investigation toward the relationship between organizational performance and infoculture and infopolitics. The convenience of being in the field of study helped learn about subtle financial "loopholes." For example, the food was prepared so that recipes used varied over years and across different cooks within a particular year. This led to hypothesizing: if the Kitchen function had not retained the knowledge of a right proportion of ingredients that guaranteed both food quality and cost-effectiveness, losses could accrue due to smaller sales and higher costs. As opposed to a restaurant business for which the retention of optimized recipes would be a trivial routine of knowledge management, the Kitchen in the Folklandia Pavilion provided a different picture. Old-fashioned house wives who prepared esoteric dishes mainly staffed this unit. Many of them owned some culinary trick and used it to give a unique twist to their dishes. Therefore, both the varying quantities of food ingredients and the "tricks" could have been money drains. Based on these insights, the performance aspect was added to the research question.

The way of completing the research question reflects the process of the interpretivist inquiry used in this study. The process was iterative and spiraling, and it consisted of three steps—ask, learn, and hypothesize, as shown in Figure 2. The Ask step implied a specific question for investigation; Learning translated into collecting data; and Hypothesizing meant creating plausible answers to be investigated further (asked and learned about). These steps were repeated (not necessarily all of them every time), thus forming loops, and one loop would lead to another, as shown in Figure 2. A certain finding—more

Ask	- What is the problem?
Learn	- Painful recall of what/how/why was done.
Hypothesize	- "Organizational Amnesia"
Ask	- What could cause "organizational amnesia?"
Hypothesize	- Specific aspects of infoculture (concept invoked from IVO) since " organizational amnesia" is a cultural phenomenon *prima facie.*
Ask	- What is the state of work manuals, problem solving documentation, financial records and IT?
Learn	- Ignorance, puzzles, and denied access.
Hypothesize	- Organizational politics around information (infopolitics) plays a role.
Ask	- What factors could influence organizational performance?
Learn	- Codifying and sharing relevant procedural and other knowledge.
Hypothesize	- Organizational performance may be affected by the existing infoculture and infopolitics.
...	
Finding	- Organizational performance is negatively affected by a clan-based infoculture and infopolitics.

Figure 2: The Process of Interpretivist Inquiry

often than not, a preliminary or draft finding rather than a final one—would crown the process. Figure 2 depicts the logic of applying the inquiry process to the research question before radical organizational changes happened in the Pavilion. Once these changes happened, the looping logic of field study led us to reevaluate past data and draft findings. Some aspects of the previous organization became clearer only through this flashback.

Note that the process of interpretivist inquiry was applied to other specific ("smaller") questions of the research agenda as well. This agenda was naturally evolving in the course of investigation. One may picture these specific questions as research tasks running in parallel or a sequence and resembling a Gantt chart. But the analogy stops with the image of task bars, since it was not possible to define much ahead specific questions for investigation, their relationships and (especially not) their time aspects. The questions would be emerging from field observation, and they were worked out as the circumstances allowed. Moreover, perhaps half of the time the researcher would just resort to "being in the field"—observing with or without participation without having a clear idea what to look at/for. Sometimes this would provide evidence for a phenomenon that was not meant to be attended to at that particular point in time. This resembled a phenomenon of *information encountering* (Erdelez, 2005), which can be understood in terms of spontaneous learning and felicitous insights. One such example is the episode from final preparations of the Pavilion in 2001, which is described below.

Findings

In this section, the organization under study will be described, and an evolutionary trajectory of the Folklandia Pavilion's infopolitics, infoculture and organization will be discussed.

Folklandia Pavilion

Folklandia Pavilion is a venue of a large festival (Folks Fest, or the Festival) that has taken place in Canada since 1972 during two August weeks. The festival is organized by a non-profit organization (the Festival Agency), which is allowed to carry a surplus income into a new fiscal year. The Festival agency provides marketing, instruction, logistical support, and other services for the Folks Fest. The festival program is designed and carried out by communities with different ethnic backgrounds residing in the Festival city. They get a chance to represent their cultural background and make some income for funding their activities. Each community participating at the Festival presents its offerings in a venue called a pavilion. There have been 40 to 50 of them in recent years, attracting about 300,000 visitors from Canada and the United States. Each pavilion is active for one week in August. Pavilions are backed by a sponsoring organization that provides financial and legal guarantees (e.g., a cultural association of an ethnic community). Other stakeholders include the travel industry of the province, hotels, grocery chains, the province's beverage distributor (a government-run corporation), and owners of buildings that are rented by pavilions.

A pavilion must, as a minimum, have a hall for visitors that includes a space for artistic performances. Additional facilities include a bar for selling beverages, kitchen, food storage, and room for demonstrating traditional crafts, selling merchandise, and entertaining children. In a standard model, a folk dancing program is presented on the stage, while guests eat and drink "goodies" purchased on the spot. Thus, pavilions generate income by selling tickets, food, beverages, and merchandise (e.g., memorabilia, folks clothing and shoes, jewelry, packaged food, and music products). Pavilions withhold all the income but the money from ticket sales, which they have to split with the Festival Agency. In recent years, there has been a trend of increasing net income both on the pavilion and Festival Agency side. These financial aspects, along with the freedom of designing the artistic program and attracting visitors in creative ways, give the pavilion characteristics of a small business. On the other hand, a pavilion is also a non-profit voluntary organization, relying mainly on the goodwill of its staff.

A special challenge in organizing and managing a pavilion is how to keep a certain level of volunteer activity over months preceding the Festival in order to act as a fully effective professional organization for one week in August. Since there is no pressure of work obligations, no clear bottom line, and no formal reward system, the level of activity of volunteers is irregular rather than steady. However, planning, money raising, staffing, scheduling, training, and procuring, as well as operational preparations (e.g., cooking the food that can be frozen) must run continuously. Then, pavilions' staff and the volume of operations start "swelling" in weeks preceding the Festival. Operations reach a climax during Festival days. At that time, support of the Festival Agency may be vital. Indeed, the Agency does function 24/7 in that period, resembling the commandant headquarters in a major military battle. The Folklandia Pavilion was struggling for years to recruit sufficient numbers of volunteers in the preparation period. During the Festival, it would engage between 50-150 volunteers.

Another challenge the pavilions have faced refers to organizing and managing. According to recommendations of the Festival Agency, a pavilion is supposed to be organized as a functional hierarchy. At the top of it sits the coordinator. This person assumes the role of a universal manager, being responsible for all aspects of pavilion activities, from the strategic to the operational level. Responsibilities include financial liability before health and other inspections. Coordinators' immediate coworkers are supposed to be the heads of various pavilion functions. These people are supposed to develop an effective organization that is able to perform smoothly during the Festival under a pressure that hardly has equivalents in small business. For example, there can be 3-5 shows a day, 50-800 visitors per show (depending on the seating capacity); hundreds of meals have to be served; stage performances (usually carried by amateurs) should be at a certain artistic level and with precise timing; safety of facilities must be continually assured; security among the crowd that can liberally consume alcohol must be maintained; and so on. People who typically are not professionals in areas they cover carry all this out. These people change over time, and can drift away unexpectedly in critical moments.

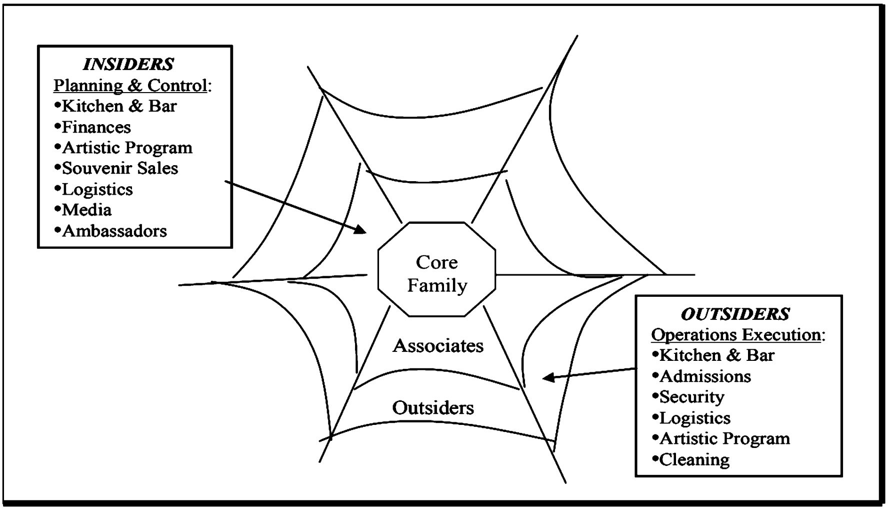

Figure 3: Organization of Folklandia Pavilion in Phase I

Given all these conditions, it is not surprising that the principle of formal authority does not apply well to this context. The corollary is that power may have various sources, including personal prestige, tradition, and ad hoc deals. In contrast to these obstacles, both the volatile character of organizational membership and the fluidity of power models imprint certain flexibility on the organization of pavilions. In principle, different organizational members can shape the organization in different ways.

Clan Era

In 2001 entirely and to a significant extent in 2002, the organization, strategic aspects, operations and most of the management of the Pavilion were in hands of a group of volunteers that had a longer tenure with the Pavilion—the insiders (see Figure 3). We call this the era of clan organization. The insiders consisted of a family (mother, father, and son) sitting at the power center ("the core family") and its immediate coworkers ("associates"), both recruited from the ethnic community behind the Pavilion. The core family used to run the Pavilion as a family business: the mother led the Kitchen function, the father controlled finances, and the son usually performed as the Pavilion coordinator and media person, in addition to shaping and performing in the artistic program. As one volunteer commented wittingly:

That family holds everything that matters in their hands. They have all the might. Just the Holy Ghost is missing. Oh, and don't be mistaken—the mother comes first."

Organizational structure of the Pavilion resembled a simple form that can be identified in small entrepreneurial organizations, such as mom and pop's business (Mintzberg, 1979). This is an undifferentiated organization in which members perform multiple roles, turfs shift and overlap, and lines of reporting as well as many other relationships are not formalized. Personal influence, agreement and improvisation compensate for the lack of formal rules and regulations. The Folklandia Pavilion fit this model. We also borrow from the concepts of clan organization (Ouchi, 1979, 1980) and power organization (Handy, 1993) in order to describe this organization. The organization of Folklandia Pavilion had a powerful agent at its center—"a spider," in Handy's (ibid.) terms. In our case, this was the core family (see Figure 3). The spider controlled the web, influencing thought and action of other inhabitants. Next to the center is the circle of associates. The core family and associates resembled a clan. Other organization members—the volunteers—inhabited the outer, marginal circle of the organization. Therefore, the term clan organization here refers to the clan (insiders) embedded in the broader organization, rather than to the organization of a clan as a special, closed group. The insiders planned, controlled and performed some operational work, while the outsiders did only the operational work under supervision of the insiders.

Infopolitics

The concept of infopolitics implies that the power of organization members and groups springs from controlling organizational information and IT, thereby making information/IT have-nots dependent for the information and IT resources. In the Folklandia Pavilion, information/IT-based power was concentrated in the hands of the insiders—firmly in 2001 and for the most part in 2002. This painted a specific infopolitics, the characteristics of which are explained below.

Running organization with eyes closed: Information power. Knowledge was the specific form of information that gave power to the insiders. This was the knowledge of the Pavilion's organization, operations and management, as well as its past, and this knowledge was monopolized (see Table 2). The insiders excluded others from important Pavilion's business in order to protect their knowledge and, therefore, their power basis. Outsiders were included in rather marginal activities and were not invited to participate in decision making activities. Outsiders were asked if they had access to work manuals or simple descriptions of the Pavilion's procedures, hygienic and technical standards that needed to be met, and other items on the operational side. Typically, they were not aware of such documentation or they thought that it did not exist. The insiders who were approached with the same question either promised to help access such documentation or denied a need for it. As a seasoned insider put it:

There are no manuals simply because we have been part of this Festival for many years,
and we have learned all we need to know and kept it in here [the person pointed to his head]. We know it, and we do it. We can run this Pavilion even with our eyes closed.

There was truth in the claim about familiarity with the operations management and execution. The familiar space (although in many respects unsuitable for hosting approximately 100 visitors per show as it usually had), the familiar type of audience, and accustomed methods of improvising material resources and procedures helped the insiders' self-confidence. However, it was also true that this organizing and management competence was confined within the Pavilion's boundaries. Communication and relationships with the Festival Agency, other pavilions, media, and various other players in the government and business environment constituted a *terra incognita.* Only coordinators would deal with these issues as they would, and many insiders seemed to believe that these external tasks were marginal. As a consequence, the Pavilion's standing *vis a vis* other pavilions was never objectively assessed. These limited and random exchanges with the environment had brought this organization more toward a closed system model.

Customized KISS: Information agenda. If the insiders could run the pavilion with closed eyes, it could have been because their political agenda had long been unchallenged. Organizational politics includes goals based on self-interest or an agenda. We developed from intial assumptions of IVO (Travica 2003, 2005), the relevant literature in the fields IS (Markus, 1983; Orlikowski 1992; Zuboff, 1984), group theory (Janis, 1982; Lewin, 1948), organization theory (Boisot, 1987; Ouchi, 1979, 1980) and field experience.

The core of the infopolitical agenda of the insiders was to preserve the status quo in the distribution of knowledge. This ensured a general status quo. This finding was a result of a longer looping process rippled with uncertainty. Uncovering infopolitical agendas is a demanding research task. As political factions group and maneuver in order to protect/seize their territory, they advance their agendas in a zigzag manner, playing along a continuum whose ends are obscurity and clarity. Sometimes, a political faction may push for its agenda without trying to conceal it. At other times, the faction can act in a manner that obscures its real goals behind smoke screen declarations and confusing messages in order to mislead opponents and attract bystanders. This ambiguous character of political behavior challenges the researcher's ability to recognize true agendas. In the process of investigation, one needs to develop an analytical model, a set of testable criteria to be used as a litmus powder for detecting agendas of infopolitics. The litmus powder for testing if the insiders' agenda was to preserve a monopoly of knowledge was a question or proposal of organizational change. We attended to interactions between the outsiders and insiders in which the former would propose some new methods at the operational or strategic level. Examples include the methods of food selection, production and preservation, organizing the souvenirs booth, designing the artistic program, and introducing computers for tracking operations and expenditures. New ideas were typically turned down or ignored. We also used the litmus test on the insiders by asking whether they had thought of doing certain things in different ways. The responses were negative and, at times, bitter. As the litmus powder turns to red in an acid solution, so would the insiders' faces turn red upon facing change-provoking questions. A number of the respondents justified their choice by arguing that there was no need to "complicate things." As if they wanted to convey the KISS motto ("Keep it simple, stupid!") used in the context of systems development in a convenient way, by implying that "simple" meant "same." Here is an example of this information agenda in action.

On the opening day of Folks Fest 2002, there were many problems with the electrical installation. Suddenly loaded with many cooking and warming devices, sections of the installation would often go down. The breakers went off, some electrical outlets burnt out, and nobody knew precisely what could be plugged in what outlet. After hours of going through a stressful trial and error process, the insiders, helped by outsiders, established a functional system. The Pavilion hall ended up in a maze of extension cords and wires with cooking and warming devices scattered around it. The setup and trouble-shooting operation was accompanied by a continuous and, at times, heated discussion on how "things worked last year." Then, three hours before opening the Pavilion gate, the device for warming food was plugged in. It knocked down the entire electrical system. The device was homemade by an insider who was a self-taught electrician (the Technician, a long-term insider). To the dismay of the volunteers present, nothing could be done to bring the system up. The Technician eventually arrived. He determined what was incorrect in the system setup, did some re-plugging, reset the warming device, and the Pavilion was ready to head for the grand opening. Some volunteers confronted the Technician on the spot. They asked if it would be wise to create a schema of a functional electrical setup and save it for the future use. The Technician resisted:

> *If I draw that schema, it would be a too complex drawing. Nobody could read it, and so I'd again have to be around to help. And I am always around anyway… So, why need a schema?*

It appeared that the insiders who witnessed this conversation shared the Technician's seemingly infallible logic. Nobody argued, no comment was uttered. Instead, consent was expressed via head nodding, shoulder shrugging, or hand waving.

We applied the litmus test to the outsiders as well by simply modifying the test question; for example, "There seems to be *no* alternative to the way this has been/can be done, is there?" Some outsiders would "turn red" upon facing this questions. But others would be rather indolent. They were unsure, or simply did not know better and went along with the stream.

The insiders saw danger in any sort of change. New methods would imply new skills and competence that could obfuscate old skills and experience of the insiders. Staying on the familiar ground was not only easier, but it was also the key to preserving the insider group's identity, cohesion, and turf. Since they monopolized operational and strategic knowledge, others depended on them in a substantial way, regardless of the capabilities they could have had.

Broader political envelop: Opposed pavilion visions. An infopolitical agenda is part of a broader political agenda—as being influenced by it and influencing it. As already discussed, the opposed factions in the Folklandia Pavilion did carry out broader agendas. Here we focus on the aspect of pavilion vision as part of these broader political agendas, which influenced their infopolitical agendas.

To the chagrin of the insiders, the new leadership emerging among the outsiders in 2002 questioned the entrenched vision of the Pavilion carried by the insiders. New recruits were traditionally taught that the Pavilion was "a family gathering" and "a hospitable place," and that the goal was to attract the community members and immediate neighbors by "a homey atmosphere and a good, affordable dinner."

Table 2: Trajectory of Infopolitics in Folklandia Pavilion

Infopolitics **Component**	***Clan Era (2001/2)***	***Teams' Era (2003)***
Infopower	Insiders monopolize knowledge on organizing the Pavilion and information on past performance as the basis of power. Outsiders show signs of resistance.	- Insiders' knowledge monopoly obliterated as outsiders acquired old and new knowledge. Knowledge sharing within/between teams. - Knowledge of modern information management and computers used as the power basis.
Infopolitical Agendas	Insiders' interest is to preserve the status quo in the diffusion of information and use of IT—outsiders' interest is to overturn it.	- Outsiders push for overall modernizing of the Pavilion's information, IT, and increasing diffusion of information.

Infopolitical Fight/Flight	- Insiders block outsiders' attempts at more systematic information and knowledge management. - Insiders lock out others from communications. - Insiders block outsiders who promote computers.	- New leadership fights former insiders by imposing more systematic information and knowledge management. - Open communication channels and team spirit promoted in battling old regime. - Flight around computer agenda brings many Pavilion members together.

In contrast, the emerging leadership framed these images rather pejoratively. They often used the term "underground" to refer to the Pavilion. "Underground" was a complex metaphor that was supposed to convey rich meaning rather than the simple fact that the Pavilion was located in a basement. Instances of using the term "underground" we coded include "a lack of fresh thinking," "non-ambitious business," "fledgling enterprise," "dull place," "a tight ship," and "a falling apart place." The image of a homey affordable dining place was countered by the lackluster phrase "workmen's cantina." The outsiders countered the insiders' vested vision in a constructive way, as well. They argued that the Pavilion was supposed to be "an economic enterprise." They wanted to move the volunteers to "think big and bold" and to compete with successful Pavilions.

Loosening vs. tightening: Fight in action. In 2001, the reign of insiders was largely unchallenged. Confrontations started in 2002, when the emerging new leadership pushed for gaining information power, clean record keeping, and a more systematic management of information. The newly recruited treasurer was part of the leadership, and fought persistently for these changes. However, as if they followed the modified KISS axiom above, the insiders resisted by sabotaging new procedures of planning publicly important expenses and of submitting timely receipts to the Treasurer. They also tended to keep communication closed in their loop, ignoring the emerging new leadership. Consistently, oral informal communication was their favorite channel (more discussion in the section on infoculture). When the aversion toward recording knowledge is entered, the picture of the mainstream infopolitics exhibits a looser approach to information and knowledge management, with a very limited role for modern IT. In contrast, the emerging, marginal infopolitics was nurturing a more methodical approach to information and knowledge management, where modern IT played an important role.

The relationship toward IT indeed created a whole battlefield in its own right. A number of members of the emerging new leadership had intermediate or higher computer skills. They insisted on creating accurate electronic information and saving it for current and future uses. The insiders blatantly ignored this technological push, meeting it with either a wall of silence or overt denial (see more on this in the next section). The main tendency of the outsiders to bring in more order and tighten the loose information procedures and flows was, therefore, effectively blocked.

In summary, in 2001 entirely and to a significant extent in 2002, the organization, strategic aspects, operations and most of the management of the Pavilion were in hands of a group of volunteers that had a longer tenure with the Pavilion—the insiders. Other organizational members were outsiders who had little say in Pavilion's affairs. The organization fit a simple form design (Mintzberg, 1979), the clan organization (Ouchi, 1979, 1980), and power organization (Handy, 1993). The infopolitics was characterized by insiders' monopoly of knowledge, localized diffusion of other forms of information, irregular management of information and knowledge, closed loop communication, computer denial, and a vested vision of the Folklandia Pavilion being a homey dining place. In 2002, this infopolitics exhibited cracks when the emerging new leadership began challenging it.

Infoculture

If the concentration of power was the landmark of the clan organization, organizational theory suggests that a complementary culture had to be in place with an equally important role. According to Ouchi (1980), organizational culture is essential to the genesis and maintenance of the clan organization. This organization thrives on a strong culture that is achieved through a strict indoctrination. The beliefs clan organization members faithfully share enable the organization to function and deliver, thus doing what formal rules do for bureaucracy and what performance indicators do for the market organization. Handy's (1993) ideas about power organization design resembling a spider's web also illuminate the cultural milieu of the clan organization. He suggests that "the web depends on trust and empathy for its effectiveness and on telepathy and personal conversation for communication" (p. 184).

Status quo assumption and trust in insiders' intelligence. All the behaviors, political maneuvering and agendas of the insiders can be attributed to a fundamental assumption that underpinned their world. This we call *status quo assumption* (see Table 3). The insiders maintained an essentially conservative word view, which could have resulted from their prolonged, unchallenged stay at the helm of the Folklandia Pavilion. They had a plenty of opportunity to consolidate their shared expectations and background knowledge, which are the dimensions of infoculture according to Bressand and Distler (1995). A personal factor could also play a role in settling of the status quo assumption. The insiders typically had a lower education and, ageing with the Festival, had past middle age by 2001.

This corollary of the status quo assumption was that the insiders' believed their way to be the best way. Consequently, they treasured their painfully acquired knowledge and guarded access to it. This knowledge was sanctified as a superior piece of intelligence (Table 3). Rituals and practices of protecting knowledge naturally followed. It is not only mistrust in novelties that drove this infoculture but also the insiders' fear that deviating from the old way would be destructive—not only to their position in the Pavilion but also to the well-being of the Pavilion. Thus, their particularistic worldview painted their perception of the whole. The status quo assumption was also mirrored in other artifacts of this infoculture, such as *document aversion* and *computers denial.*

Document aversion. As the discussion in the previous sections indicated, the insiders refused to document their knowledge and did not keep records on operations in a methodical manner. We term this attitude *document aversion.* From the perspective of self-preservation, the insiders could reason that documenting knowledge could have led to undesirable outcomes. Knowledge could leak to the outsiders and thereby lose its sacred character. Heretic thoughts could occur, such as the idea that the insiders could be replaced. Similarly, availability of complete, clean records on costs and on organizational performance could have raised questions concerning the background causes and possibility of different outcomes. In general, uncontrollable changes could have been triggered.

Document aversion can be explained in terms of Boisot's (1987, 1998) framework. Documenting knowledge is a form of *codifying information.* The simplest form of codifying is writing down what is known. Codified information increases the scope of *information diffusion.* Since the clan organization attempts to keep information within the power center, codification or documenting of knowledge is neither appreciated nor practiced. What was the alternative to documenting? Human memory. Instead of relying on documentation, the insiders relied on their own memory. Although this preserved their order, they had to pay the price of a painstaking recall. High time costs and information loss were the first order consequences, triggering rippled effects on organizational processes and, in the ultimate instance, organizational performance.

Praising paper trail over "useless" computers. The literature providing the backdrop to our concept of infoculture discussed above had identified computer technology as an important generator of infocultures (Deal & Kennedy, 1999; Orlikowski, 1996; Orlikowski & Gash, 1994). The clan era in 2001, however, had seen more of a paper trail than of computers and, thus, it can be characterized as a pre-computer infoculture. In 2002, computers were introduced in some major operations (tracking of expenditures, communications, marketing). Still, all this was done on the margins rather than in the mainstream infoculture, which valued paper as the technology of choice. We found that a number of Pavilion members characterized paper as "safe," "always available," "natural," and "cheap."

Although paper trail reigned, it was really used to a limited extent due to the document aversion (discussed above) and a preference for oral communication (see below). When we finally obtained access to paper records, we realized that about 95% of the records preceding 2002 were paper receipts and paper notes stored in boxes labeled by Festival years. The level of organizing these records was low. The receipts were in piles held together by rubber bands, and the grouping was based on dates and types of products (e.g., drinks, food, and accessories). The notes contained some summary information, but no clear summary of overall costs and revenues could be found. Therefore, the venerated paper trail was Spartan, or meager, scanty, insufficient for the purposes of accounting and financial control.

Being anchored in the paper world, the insiders maintained an adamant anti-computer stance and managed to influence many volunteers in this direction. In interviews, anti-computer opinions were aired clearly, and we organized them in three categories. One is *computer illiteracy*:

> I am not a computer person, and I don't know how I am supposed to use it! *(An insider performing in the role of cashier)*
>
> What do we need a computer for? I can do my part well without any computer, and I don't see how it could help me. *(A volunteer working on ticket sales)*

Table 3: Trajectory of Infoculture in Folklandia Pavilion

Infoculture Component	***Clan Era (2001-2)***	***Teams' Era (2003)***
Beliefs -- *Behaviors*	*Status Quo Assumption: Historically acquired knowledge of organizing and running the Pavilion should be preserved within the insiders' circle.* -- *Rituals and practices of keeping knowledge within the insider's circle and of excluding the insiders.*	*Transformation Assumption:* *Professional knowledge from various domains should be combined in functional teams and used for improving income and Pavilion's offerings. --* *Active acquisition of procedural knowledge and more sharing of various knowledge and new information in and across teams.*
	Valuing insiders' intelligence.	*Valuing teams' intelligence.*

	Aversive attitudes toward documenting knowledge and methodical records keeping. Trust in human memory.-- *Irregular management of information and knowledge, and rituals of memory recall.*	*Positive attitudes toward systematic records keeping, documenting new knowledge and trust in technology-supported memory.--* *More systematic management of information and knowledge.*
	Valuing paper trail and disbelieving computers. The emerging leadership in 2002 airs appreciation for computers. -- *Use of paper trail in support to Pavilion's operations. The emerging leadership in 2002 counters by using computers for limited records management.*	*Positive valuing of computer; pragmatic attitude toward paper trail.* *--* *A high usage of electronic information technologies from operations to marketing and financial management.*
	Preference for informal oral communication. The emerging leadership in 2002 counters by praising email for convenience and expedience. -- Communicating face-to-face and via telephone. The emerging leadership in 2002 counters by using email intensely.	*Preference for documented and sometimes more formal communication.* *Email valued for documenting capabilities.--* *Communicating via email, memos and formal meetings. Multipurpose use of email across the Pavilion. Email becomes backbone to organizational memory.*
	Excluding IS from the beliefs system. -- *Behaviors incongruent with logic of IS.*	*Attributing value to IS. --* *End users develop IS and intensively use them.*

Another category depicting the anti-computer stance refers to *computer apprehension.*

> Computer, huh? I've got no clue what's going on in that thing [computer]… How can I trust it is going to do it right? *(The 2001 treasurer)*
>
> I'd rather do my work in old ways I am familiar with. I fear I can make some damage if I touch a wrong key and have the information inside a computer lost. Perhaps younger, trained people can see a value in computers, but not me. I do not use computers in my own business either, and I'm doing fine. *(A volunteer performing in various operations)*

Yet another category of anti-computer beliefs included a variant of the *not invented here* attitude, which can be seen as yet another reflection of the general status quo assumption.

> Computer has no use in this Pavilion! Our job is to represent our cultural heritage, and that is where we should focus our efforts—not on computers. *(An insider)*
>
> Why would I need a computer? I call my supplier to bring me the merchandise… I sell things I've got… I collect money, count the cash at the end of the day… I write down numbers in my notepad, and that's it! Where could I use a computer in my business? It [computer] might have place in some other parts of the Pavilion, but not here. *(A souvenirs booth staff)*
>
> We lived without computers so far, why would we need them now? And there are the things we need more urgently than a computer. *(A member of the core family)*

Therefore, the denial of computers had several faces—*computer illiteracy, computer apprehension* and *the not invented here attitude.* Paper trail was favored. But, as already discussed, it was not used in a systematic way. Enter the rituals of recalling past solutions from human memory cited above. The result is an *irregular management of information and knowledge*—yet another dimension describing this infoculture.

The cracks in this infoculture, however, surfaced in 2002. Computer use was an issue of contention. The most dramatic example was that the new treasurer (an outsider) based accounting of costs on Excel™ applications, which he developed. Another big example was communication via email (see the next item below and the section on the teams' era). Still, the use of computers was limited to a minority of Pavilion members and select tasks. It appeared that the insiders neither cared much nor understood what was going on. At any rate, they refrained from publicly blocking the outsiders.

Oral communication and rejection of information systems. Another infocultural aspect was a tradition of oral communication. As Davenport and Prusak (1997) have pointed out, the choice of communication channels is a dimension of infoculture. The insiders' first choice was face-to-face communication, and the second was the telephone channel. They claimed that were the best way to "understand each other" and "get things right." Recall Handy's (1993) proposition that this sort of organization "depends on telepathy and personal conversation for communication" (p. 184). Oral communication is the natural choice in this context. However, what worked well within the insiders' circle, was not truly appreciated by others. Some members of the emerging new leadership pointed out that "it was not easy to get the people in charge [the insiders] to talk on the phone." One obstacle was the telephone tag and another appeared to be the insiders' reluctance to return calls. These outsiders countered the mainstream infoculture by using email frequently and praising it publicly for convenience and expedience.

Note that the choice of oral communication was consistent with the attitude of document aversion. Oral communication left no trace, and it could be interpreted arbitrarily in later recalls. When the propensity for oral communication is coupled with document aversion and anti-computer values, yet another aspect of the clan infoculture emerges. Since information, communication and IT are parts of any IS, a positioning on these three aspects may indicate how IS fairs in a certain infoculture. Ouchi (1979) has suggested that IS are not a priority in a clan organization because it does not have the needs that IS are designed to fulfill. This organization does not track organizational performance in order to compare it against predefined criteria, as the market organization does. And unlike bureaucracy, the clan organization does not adhere to formal procedures either. Therefore, there is little/no need for IS in the clan organization (cf. Hatch, 1997, 337-41).

We should note that the concept of IS implied in Ouchi's (1979) argument is also shared in the IS field: an IS is a rational means of achieving rational ends—systematic information management based on IS leads to quality information (accurate, complete, timely), which, in turn, supports certain organizational objectives. The insiders in our study did in fact deny IS as a rational means. They had an aversion toward computers and systematic records keeping and preferred undocumented communications. This denial, however, had rational ends because it helped prolong the existing clan organization. Therefore, from the perspective of the clan organization, the denial of IS, and than acceptance, is a rational means toward rational ends.

Although the IS denial was the dominant tendency in the clan infoculture of the Folklandia Pavilion it was not the only belief and behavior concerning IS. The organization already carried the seeds of its antipode that originated among the outsiders in 2002. These seeds were going to transform the Pavilion and bring it into the next phase in its historical trajectory, which is the topic of the next section.

In summary, the infoculture of the clan era was characterized by a status quo assumption, trust in insiders' intelligence, document aversion, disbelief in computers, valuing of paper trail, oral communication, and denial of IS. In contrast, a marginal subculture emerged in 2002, opposing the mainstream infoculture in many respects.

Infopolitics and Infoculture in Teams' Era

The Era of Teams dawned in 2003. A new leadership was established that enlisted some members of the emerging new leadership from 2002, a number of new volunteers in lead positions, and only one member from the old insiders circle. The recruitment/selection and initial radical changes of the organization of the Pavilion was the deed of the coordinator, coordinator assistant and program leader. These three worked out many things as a coherent team of professionals. The next significant change was that the Pavilion was moved from its old "underground" to a school in a wealthy neighborhood. The seating capacity was tripled, and access to modern facilities for catering and entertainment obtained. A new function called Kids Corner was introduced, the Souvenirs function was eventually put on track with diversified offerings from food to video and music products, guest musicians were brought from out of town to enrich the artistic program, and more was done on the marketing side (see organization chart in Figure 4).

A new organization of the Pavilion was established. Organizational structure became more differentiated as new functions were introduced

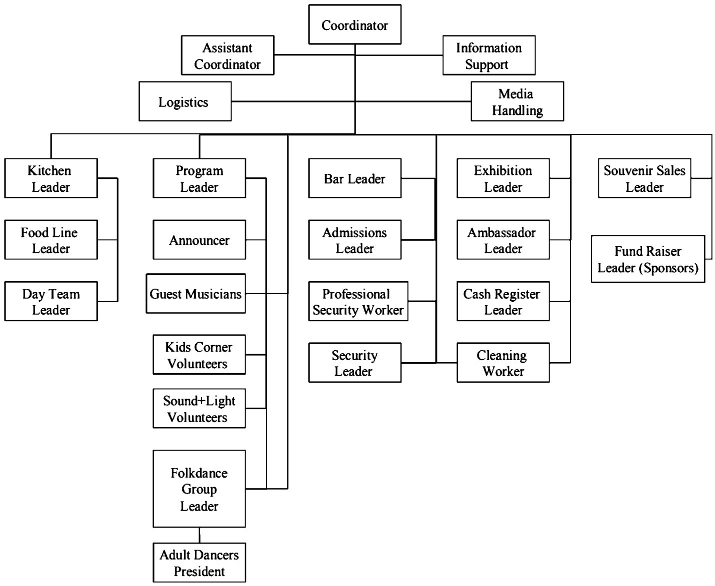

Figure 4: Organizational Chart of the Folklandia Pavilion in Phase II

and lines of reporting defined. Each function was carried by a team, which was headed by a leader. Each leader reported to the coordinator, although there were some crossed lines of reporting, bringing in an aspect of the matrix organization (e.g., the folk dance group leader reported both to the program leader and the coordinator). Thus, the Pavilion became organized in a more complex way that combined characteristics of team organization and flexible hierarchy.

Fresh Air in Infopolitics

Terminating the knowledge monopoly of the insiders decisively changed infopolitics in the Folklandia Pavilion. From the perspective of information diffusion (Boisot, 1987, 1998), the new infopolitics increased diffusion of information in its various forms, thus destroying the pattern of diffusion localized in the insiders' circle. The concepts of centralization/decentralization of information and IT that help understand infopolitics in general (Hanseth et al. 2001; Markus, 1983; Orlikowski & Yates, 1994; Travica, 1999; Zuboff, 1984) are useful in explaining these changes. While the old regime centralized information to its exclusive circle of power, the new regime pulled toward decentralization of information and IT.

As indicated in Table 2, the trajectory of the new infopolitics had origins in the clan era since the former was emanating as an antipode to the clan infopolitics. The new infopolitics evolved around the assumption of organizational change, which covered many bases—from organizational structure, politics and culture to leadership and management. Building the new organization was coupled with the acquisition of new knowledge, and learning became the main imperative. This imperative had a bearing on infopolitics by drawing a demarcation line between those who accepted it and those who did not. The Pavilion facilities, its new environment, and the challenges of its new functions and an increased volume of operations were a *terra incognita* for all. The challenge of the unknown and the urge to learn discouraged those who believed only in the old ways and resisted learning the new. Indeed, the majority of the old insiders could not see themselves in the new order and excluded themselves from the Pavilion. The insiders offered several justifications in public: "I do not know where the Pavilion is now;" "I don't know how to get there;" "The new Pavilion is far from my home/work;" "I do not know anybody in that new neighborhood;" "I got no clue how things work there."

In addition to knowledge of organizing and running the Pavilion, knowledge of modern IT and information management consolidated the new basis of power. The new leadership had an advantage in this respect—with an exception or two, leaders of all the teams were minimally at the intermediate level of computer literacy. Other Pavilion members typically had less developed computer skills. The difference was critical in cases of applications used on a daily basis, such as email. A new mode of power differentiation developed on this basis, thus corroborating previous evidence that the speed, direction, content and pattern of information flows have to do with power (Danziger et al., 1982; Markus, 1983). A remarkable example of a power loss associated with technological change was the president of the Board of the Pavilion's sponsoring organization. Of all the Board members, this person lagged in adopting email. An apparent consequence was that he was always out of the loop of new information, which was circulated fast via email. This was visible at meetings, where he struggled to catch up and sometimes failed to act as an effective decision maker.

One volunteer described the overall changes at the end of the Festival succinctly: "It felt as if the windows that were toughly closed over a long time were opened at last to let the fresh air in." In addition to letting the fresh air of new knowledge in, energy was spared by the cessation of poignant political and infopolitical battles of the past. The new infopolitics in particular propelled more open communication channels. The sharing of knowledge and information was continuously stimulated, and the new leadership made an effort to make public most of the newly created information and knowledge. Thus, the diffusion of information was significantly increased (Table 2). In the terminology of Davenport and Prusak (1997), the new infoculture showed a preference for facts over rumors.

Images of the Pavilion being solely a "homey, affordable dining place" (the vested organizational vision of the old insiders) gave way to the slogan "the Pavilion is a competitive economic enterprise." The team at the Pavilion's helm (the coordinator, assistant coordinator, and program chair) was providing a didactic example of this business-focused vision. They functioned effectively as true professionals; although not all of them related to each other in private life (the coordinator had links with two other members, while these two were distanced by some old unresolved dispute). Putting professionalism before private interest sent the message of how business logic could be brought to the fore in this enterprise, which blended aspects of volunteer organization and small business organization.

Incubation of New Infoculture in Teams

These changes were complemented by a major transformation of infoculture in the Folklandia Pavilion. First, the status quo assumption of the old infoculture was no longer in circulation. Instead, the assumption of transformation, which was initiated by the rebelling outsiders in the clan era, was brought to full blossoming. Functional teams became the central change agent, guided by the new leadership. These teams were nurtured as a new form of intelligence, driven by two clearly communicated strategic goals—to increase the Pavilion's income/profit margin and to improve the Pavilion's overall offerings. The learning process reached beyond Pavilion walls as the new leadership made an effort to acquire externally more advanced methods of organizing and management (e.g., from other pavilions and from appropriate domains of professional knowledge). The ideas acquired this way would then be incubated in the functional teams in order to facilitate ripening of solutions fit to the Pavilion's characteristics. New procedural knowledge was immediately shared via email and, occasionally, in meetings—within teams and between them.

Positive attitudes toward systematic records keeping and information management in general were planted and systematically cultivated in the new infoculture. This was related to the regularity in information and knowledge management that once were considered subversive political practices (see above). For example, the new leadership used every opportunity to point out how a lack of historical records, work manuals and other documentation produced loss of time, resources and money. These were moments of a dramatic reinforcement of the values of maintaining a proper information management. In one such situation, the coordinator practically demonstrated to some team leaders and the sponsoring organization's Board that the lack of a procedure for determining proportions of meal ingredients was a likely cause of loss in the food income in the past.

The new leadership staked much of the new infoculture on affirmative valuing of computer technology. Paper trail continued to be used where it was useful. This blending of IT types, in spite of the strong predilection for computers, suggests that the new infoculture took a rather pragmatic approach. Again, this was in stark contrast with the dogmatic inclination toward paper and the computer denial that characterized the old infoculture. Computers were introduced in support to planning and a wide range of operations. For instance, most of accounting and financial data (including transactions with the Pavilion's bank) were managed electronically. This was an extension of changes introduced in 2002, and an example of end-user systems development. Another big example of IT deployment concerns marketing. A Web site was developed and advertised to travel agents and media, with the ultimate goal of attracting more visitors to the Pavilion (travel agents participated in the process of bringing tourists from the United States to the Folks Festival). This was another example of end-user system development. The initial idea of developing a few pages that would briefly inform on the artistic program, show times, menu, and driving directions grew up into a more ambitious project. New pages were developed in a seemingly haphazard way, each adding a new detail and helping to deepen and broaden the picture of the Pavilion. The site received some affirmative evaluations from external players, and the Pavilion's volunteers liked seeing their names and pictures on it. However, a formal evaluation of the effects of the site was never conducted.

If the proportion of paperwork vs. digital processing is considered an aspect of infoculture (Sarker & Lee, 2000), the new infoculture in the Folklandia Pavilion tilted the proportion toward the digital side. Intensive use of digital IT was extended into Festival days. Two computers connected to data projectors and TV screens were used to run slide presentations. The presentations supported the artistic program and featured a list of the Pavilion's sponsors, thus achieving a two-pronged benefit. In addition, sound masters connected a PC to the sound system, and managed the music playback this way. This allowed for a more flexible programming scheme since the selection of folk dance tunes could be easily rearranged from show to show. All this helped to improve the delivery of the artistic program. Applications of Excel™ were also used for tracking and processing the admission and income figures on the spot were used for this purpose. Improvements in reporting resulted. For example, cash flow information was completed and made public by the end of each Festival day. Comparisons with the performance in the previous year were also generated. This information was, then, filtered into reports prepared for different audiences—the Pavilion staff, the Board of the sponsoring organization, and the Festival Agency. The reports were emailed and dispatched in paper form. They were also stored as part of organizational memory for future use.

Email-Based Memory

In contrast to the predominance of oral informal communication of the clan era, the new infoculture favored documented and more formal communication. Communications between the Pavilions leadership and the Board of the Pavilion's sponsoring organization acquired a written standardized form. The coordinator introduced a report for bi-weekly meetings with the Board that contained four sections: (1) Tasks Accomplished, (2) Tasks To Do, (3) Pavilion's Needs, and (4) Real/Potential Problems. These reports were distributed by both e-mail and mail and they served as the main vehicle for planning and control execution of the Pavilion's preparations.

There was no real planning behind the selection of kinds of digital IT used in the Pavilion. The main guide was information needs. For example, the need to track the performance of the Pavilion better than in the past led to electronic management of accounting and financial data. Another factor was availability of technology, since all software and hardware used were in private possession of the Pavilion members. Enthusiasm of the volunteers was responsible for the end-user development (the Web site, Excel™ applications). Personal preferences were likely to play a role as well. The typical example was email, which painted remarkably the new infoculture.

In 2002, the use of email was a behavior belonging to a counter-infoculture. A method of indoctrination the emerging new leadership used was to make themselves unavailable via the telephone, while answering promptly to both telephone and email messages. In the teams' era, email became a true "killer" application with a high adoption rate. If convenience and expedience were the benefits that propelled email in 2002, the documenting capability promoted email into the key technology of organizational memory in 2003. Some of the 2002 email folders became a repository of information for a number of volunteers who learned how useful could be old email messages containing descriptions of certain organizational procedures, ideas, traces of problem solving and decision making, and supplier data. Analysis of a convenient sample of email folders indicated existence of the message genresdefined by Orlikowski and Yates (1994)—memo, dialogue, proposal, and ballot. The content of a *memo* message would be the documentation concerning scheduling (e.g., a breakdown of tasks against a timeline), purchasing, sales and inventory reporting (e.g., the treasurer's reports on daily cash flows), instructions (e.g., how to set up dishwashing sinks), decisions, or authority recommendations. A message in the *dialogue* rubric would cite parts or entire messages and respond to these; thus, the term *response* signifies this sort of message as well. A *proposal* message would contain a stimulus for thinking and action (e.g., "Can we do something with the sound, which is still bad?" or "I think that the beer garden should offer more than beer—music, discrete lights, a special atmosphere"). A *ballot* would contain someone's invitation to taking a vote or one's vote (e.g., "What do you think about setting up a Kids Corner in our Pavilion?").

We identified yet another message genre we call *reminder*. Many messages resembled the form of dialogue, but their purpose was not just to respond to a cited message. Instead, a reminder message would cite a memo (report, instructions, decision, recommendation) in order to develop a proposal, initiate vote, or create new/extend old memos. For example, one person noted via email that some younger volunteers showed a lack of care for the inventory in the rented facilities, and asked rhetorically if something should be done about that (proposal). This sparked a chain of messages with relevant observations (dialogue) or with ideas about solutions (proposal). The next in the chain of messages was an email from the assistant coordinator that summarized the problem, cited some of the previous messages, and raised the question: "Should we make a guide on volunteers' behavior?" This message was followed by yes/no votes. Therefore, the assistant coordinator's message belongs to the *reminder* category because it used cites and initiated voting.

Reminder messages showed up in external communication as well. The new leadership had to maintain continuous contact with the representatives of the rented facilities as well as with a partner pavilion, which was going to use the same facilities in the alternate week of the Festival. Being able to pull out previous decisions and policy statements (both are in the memo category) turned out to be very useful in certain situations. In one of them, the building was double booked for the final rehearsal, and the coordinator successfully used his old email with a booking request (a memo) to prove his booking (reminder). In another case, the coordinator used a reminder email citing an important promise of a representative of the facilities that the representative was denying. Faced with the documented promise, the representative balked. It is apparent from this discussion that a completely new corpus of values, norms and behaviors carved an essential role for email in this infoculture. Email became *par excellence* a technology of management at different levels and in various organizational domains, particularly used for informing, coordinating, negotiating, planning, scheduling, and decision making.

The emphasis on email in this infoculture had a good fit with the beliefs on both documenting practices and on computers. Put together, these aspects indicate that a belief in IS as rational means for achieving performance goals was superior in this new infoculture. New information and knowledge was created, shared and maintained in a more systematic way than ever. This finding parallels the indication from Orlikowski's (1996) study that assumptions and values concerning preservation of knowledge could be a key aspect in a new culture.

In brief, the sections above discussed findings that address the first part of the research question concerning the aspects of infopolitics and infoculture in the Folklandia Pavilion. The second part of the research question addressed the relationships that infopolitics and infoculture formed with organizational performance, which is the topic of the next section.

Improved Pavilion Performance

Changes in infopolitics and infoculture of the Pavilion led to improvements in the financial bottom line. All financial indicators increased considerably in 2002 and 2003 including gross profit/revenue ratio that increased from 38% in 2001 to about 60% in 2002 and 2003. This means costs of sales were brought under certain control already in 2002. Although the clan organization still reigned as the discussion above showed, it was challenged by the emerging new leadership that had fingers on some important money buttons (purchasing, tracking expenditures, and income). Some improvements in financial discipline followed. Further improvements were achieved in 2003, even though the gross profit-revenue ratio was somewhat depressed by higher costs of sales cause by a larger volume of operations. The net profit was more than doubled in comparison to what was made in the clan era, despite some new cost categories (professional security service, contract costs, and a loss in sales due to a failure of the liquor vendor).

Qualitative assessments of the pavilion performance confirm the same increasing trend. During the Festival in 2003, the visitors (both ordinary persons and various officials) and media appreciated what the Folklandia Pavilion offered. Some of the typical comments were: "This is one of the best pavilions"; "Everything was much better organized than before"; "I felt that every staff knew what they were doing"; "The service was excellent"; "I really had fun." A number of team leaders and other volunteers also made positive remarks regarding the management and operations of the Pavilion.

The tightened financial discipline in purchasing and other expenditures in 2002 was a result of partial changes in managing the Pavilion. Performance improvements in 2003 resulted from changing the organization and further improving its management. Part of these changes happened in the domains of infopolitics and infoculture. We argued above that the fundamental conservatism in infopolitics and infoculture in the clan era kept new people and new ideas at margins. Confronting the old way in 2002 and overthrowing it in 2003 meant instituting a new infopolitics and infoculture. The net effect of changing these was in improved efficiency and effectiveness of many organizational processes. A dimension of a possibly large importance was what Sarker and Lee (2000) call "match between technological infrastructure and process efficiency needs." The many changes of IT infrastructure that the Folklandia Pavilion experienced in the teams' era led to a better match between IT and process efficiency needs. Technology helped meet efficiency requirements of a number of processes, among which the most deficient used to be those of knowledge management, accounting, financial control, performance tracking, scheduling, and coordinating.

In summary, the era of teams introduced a new infopolitics and infoculture in the Folklandia Pavilion. The knowledge monopoly of the old regime was dismantled and more open communication and sharing of information in its various forms was practiced. Teams became the centerpiece of the new order, and an entire email culture emerged. The Pavilion achieved a higher level of performance.

Epilogue

The management model set in 2003 continued to be used successfully in subsequent years. Financial results of the Pavilion improved, and the overall performance held at a high level. This was achieved in spite of changes in the Pavilion leadership over years. Some of the former insiders volunteered in the Pavilion. This, along with the shared data repositories (email folders, financial records, recorded instructions on organizing pavilion functions, how-to-do manuals, and other shared sources of information), facilitated knowledge transfer to new recruits. In 2007, the Pavilion model was taken by a new sponsoring organization established by the dance group that spun off the previous sponsor. The organizational model continued yielding a high performance.

Summary and Discussion

The case study presented in this chapter has several limitations. The first refers to the rather unique type of organization under study. It was a hybrid of volunteer and small business organization that is not very common. This unique organization had certain flexibility due to the temporary staff and leadership that allowed rather swift organizational changes to take place within a relatively short period. However, this unique character imposes limits to generalizing findings of the study.

Second, the IT involved in the case is either pre-electronic (Phase I) or basic (Excel^{tm} applications, email) with rare instances of higher types (Web technology). The choices and particular uses of IT were dependent on the particular people involved. They brought their own IT into the Pavilion business, and evolved the spectrum of IT use according to their capabilities. For example, although the demonstrated straightforward use of email in support to organizational memory was an interesting invention, one can certainly think of various alternatives with richer retrieval and organizing capabilities. Therefore, it could be challenging to look for cases that are comparative on the IT infrastructure and its use.

Third, findings on causal connections discussed in the section on the financial gains of the reorganized Folklandia Pavilion draw on a simplified modeling. The new infoculture and infopolitics could have led first to process gains, and then improved process efficiency and effectiveness could translate directly into monetary gains. These process aspects and their effects, however, were just tentatively addressed in this article because the focus has been on infopolitics and infoculture. The last limitation follows from those listed above: this case study can be taken only as a limited test of the part of the IVO framework concerning infoculture and infopolitics. New tests on different types of organizations with different types of IT and information and knowledge management are needed for validating further the concepts of infoculture and infopolitics and the broader IVO framework.

Notwithstanding the limitations, the study's goal of pilot testing the concepts of infopolitics and infoculture is accomplished. This approach has informed us that the Folklandia Pavilion passed through two development phases. The first was a clan organization (Handy, 1993; Ouchi, 1979, 1980). It covered years 2001/2, when a group of seasoned volunteers—the insiders—used a monopoly of knowledge and information as the basis of power over the majority of the Pavilion members—the outsiders. The insiders' agenda was to preserve the status quo in the distribution of information and in use (or better disuse) of IT. Political maneuvering of the insiders was in function of these goals, and they blocked action that would threaten to transform the Pavilion into something else but their "homey, affordable dining place." The insiders followed an assumption of status quo, and strived to keep knowledge within their circle. They were adverse to documenting knowledge, methodical records keeping, computers, and information systems. They also preferred relying on human memory rather than technology, valued paper trail over computers, and favored informal oral communication over mediated and formalized one. They were deeply vested into their familiar world, which for them was the best of all possible worlds.

The clannish infopolitics and infoculture was cracked in 2003 and defeated in 2003 with the emergence of a new Pavilion leadership that introduced a teams' era. A main battleground evolved around information management, computers, and vision of the Pavilion's goals. The conflict resembled the ones identified in the relevant literature (Barley, 1986, 1990; Danziger and associates, 1982; Hanseth et al., 2001; Kunda, 1992; Markus, 1983; Orlikowski, 1992, 1996). At the management level, the Pavilion was moved to a wealthy neighborhood, and a new organization was established based on functional teams connected into a shallow, flexible hierarchy. The termination of the insiders' knowledge monopoly gave way to a new power distribution. A significant segment of the power basis of the new regime was knowledge of using newly deployed modern IT and thereby supported information management. This finding corroborates previous evidence on the relationships between IT and power (Barley, 1986, 1990; Markus, 1983; Zuboff, 1984) and between knowledge and power (Barley, 1986, 1990; Crozier, 1964; Zuboff, 1984). The power change in the Folklandia Pavilion also confirms the proposition that digital IT is a flexible technology that can be used for supporting various interests (Danziger et al., 1982; Zuboff, 1984).

The infoculture of the teams' era was premised on an assumption of transformation based on professional knowledge and continuous learning. The teams carrying various functions in the Pavilion became agents of intelligence suitable to the new era, incubators of new ideas brought from the Pavilion's environment, and developers and testers of new methods of work. A vision of economic enterprise provided guidance—increase income, improve service. In a stark contrast to old ways, the new organization deployed a more systematic management of information and knowledge, and used various applications to support this. Digital IT and IS figured prominently both in the value system and in work practices. Through practice and ritualistic reinforcement of values attached to it, email was promoted into a key technology in the new infoculture. Email formed the technological foundation of organizational memory. This memory was instantiated in the genres of memo, dialogue, proposal, ballot (Orlikowski & Yates, 1994) and in a newly discovered "reminder"—the message that cites some memo in order to develop a proposal, initiate vote, or create new/extend old memos. This sort of message was used beneficially both within the Pavilion and in communication with external stakeholders. From the management perspective, email found place in informing, coordinating, negotiating, planning, scheduling, and decision making activities.

The discovery of an entire infoculture corroborates previous evidence that new IT can trigger broad cultural changes (Orlikowski, 1996). In contrast to this study, however, our case shows that the changes could be not only opportunistic but also a result of a planned, concentrated effort. Note, however, that different types of organizations and IT are addressed in these studies, and that the organization in our study has no permanent membership. Furthermore, contrary to Deal and Kennedy's (1999) cautioning about undesirable cultural effects of computers, we found that computer-related changes in the Folklandia Pavilion were beneficial. The proposition of these authors that computers can be instruments of breaking old social ties turned out to be true. However, these ties belonged to an obsolete clan organization that hindered the development of the Pavilion, and so breaking them created opportunities for improving the Pavilion and its performance.

Research Contributions

From the research perspective, the study of the Folklandia Pavilion has provided an initial validation of the concepts of infopolitics and infoculture, both based on the IVO framework (Travica, 2003, 2005). The study identified several dimensions of infopolitics, some of which have parallels in the relevant literature. These are the speed, direction, content and pattern of information flows (Danziger et al., 1982; Markus, 1983), centralizing/decentralizing control over information, knowledge and IT (Hanseth et al. 2001; Markus, 1983; Orlikowski & Yates, 1994; Travica, 1999; Zuboff, 1984), political agendas aiming at preserving a status quo in the diffusion of information and use of IT or at breaking it, and blocking versus supportive political behaviors with regard to open communication, modern information and knowledge management and promotion of computers. The study also confirmed some dimensions of infoculture that are hinted in the literature and discovered new ones. These refer to the selection of communication channels, information sharing practices, and preference for facts or rumors (Davenport & Prusak, 1997), clannish codification and diffusion of information (Boisot, 1987, 1998), shared expectations and background knowledge (Bressand & Distler, 1995) as cultural binds, assumptions regarding instrumentality of IT and information in accomplishing performance goals (Orlikowski & Gash, 1994), values and behaviors related to documenting of knowledge (Orlikowski, 1996), values and practices related to paper trail and electronic IT (Sarker & Lee, 2000), conservative versus progressive values and practices concerning IT and IS, beliefs about the character of intelligence, positive versus negative valuing of computers, and team-based codification and diffusion of information.

The study also found that infopolitics and infoculture influenced organizational performance. While the clannish infoculture and infopolitics suppressed the performance of the Folklandia Pavilion, the team infoculture and infopolitics of the team era infused beneficial changes. In particular, better information accrued for the management and stakeholders. Better cost accounting supported a tighter financial discipline. Planning, control, operations management and execution, strategizing, coordination, and personnel management benefited from the new infopolitics and infoculture as well. Communication became more efficient and supportive of better planning and control. Richer and faster organizational memory utilizing email helped save time and money and be more effective. As a result, financial performance of the Pavilion improved.

Further validation of the concepts of infoculture and infopolitics is needed through investigating different organizations and IT infrastructures. Also, IS should be studied in more depth in different stages of their life cycle, in the manner system adoption has recently been approached from the perspective of infoculture and infopolitics (Travica, 2007, 2008). Finally, qualitative research can be complemented with quantitative investigation with the goal of arriving at measurement instruments for IVO concepts. This line of research would advance IVO and, in turn, contribute to informing science.

Theorizing on infoculture and infopolitics contributes to both IS theory and organization theory. The case informs that different organizational designs are based on different forms of infopolitics and infoculture, which, in turn, owe their origin to organizational informing agents. In other words, information and IT inform organizational design. In further follows from the case that transition from one design and managerial model to another is fundamentally based on moving from one model of infopolitics and infoculture to a different model. In addition, there are ramifications for organization theory with regard to organizational design/form and management. Although the organization studied is not of a very common type, it mirrors some universal characteristics of small organization or the simple form (Mintzberg, 1979). The case suggests that the specific origins of shared characteristics can vary across different models of the simple type. For example, restricted sharing of knowledge resembling what we found in the Pavilion could be also found in a small professional organization. These can also share one common cause—limited resources that are prohibitive of formalizing information management and introducing more sophisticated IT. However, in contrast to the political motives of the Pavilion's insiders, members of the small professional organization may not actively share knowledge because it is simpler and cheaper to operate that way (regular knowledge sharing incurs opportunity costs, such as a loss of billable hours), while mature professionals still manage to get the job done well.

Contribution to Informing Science

Informing system consists of informer, delivery system, and client, placed in a context and connected in a chain or a loop fashion (informer turns into client and client into informer, or informer and client are the same actor). The case presented in this chapter contributes in several respects to this fundamental model of informing science.

First, infopolitics and infoculture paint a layer of the context in which an *informing system* is embedded. Second, the case reveals relationships between this context and the three entities of an *informing system*. In particular, the informer vested in a status quo infopolitics and infoculture may tend to keep an informal delivery system. This is what the insiders in the clan era were doing for years, maintaining oral communication, knowledge in memory rather than in external representations, and loose data records. This informal *informing system* was surviving as long as the client cooperated. However, the *informing system* unraveled when the reformers confronted the clan organization. In the process of supplanting the clan organization by a team-based organization, one of the first moves the reformers made was to formalize several delivery systems (e.g., those for communication, reporting, and accounting). Indeed, they leveraged these systems to change infopolitics and infoculture. Therefore, the infopolitics and infoculture context influenced the delivery system, and a new delivery system influenced the context.

The third contribution to informing science is in discovering the evolution from the informal to formal *informing systems*, which is outlined in the preceding paragraph. The active role played by the informer conveying information via oral communication was superseded by delivery systems that stored data and knowledge representations. The resulting evolved *informing system* was more formal and less informer-driven. It assigned a more active role to the client, who was enabled to access and interpret data on their own. In addition, the role of informer ceased to be a privilege and became a collegial task shared by all. This more balanced *informing system* improved the quality of informing in the observed organization. It is plausible that an *informing system* in a small professional organization also involves an informal delivery system while, contrary to the Pavilion in the clan era, deploying bi-directional communication between the informer and the client. This variation depends again on the context within the respective *informing systems*, which is partly explained by the concepts of infoculture and infopolitics.

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Chapter 17

Informing Citizens in a Highly Restrictive Environment Using Low-Budget Multimedia Communications: A Serbian Case Study

Aleksandar Spasic and Miloje Nesic

Introduction

The primary objective of this chapter is to show how the informing science perspective can help us better to understand the multimedia communications in restrictive environment caused by repressive regime.

The chapter provides insights into media suppression in the former Yugoslavia and how the independent media overcame the political, financial and technical constraints to play a key role in informing their citizens using communication standards and methodologies within the technical limitations.

The case study presented here describes an inexpensive network for news exchange between TV stations, as well as a system for news production and distribution in a highly restrictive environment developed by the authors. The system was initially designed in response to the news restrictions established in former Yugoslavia by Slobodan Milosevic. During this time, independent media were periodically disrupted or banned. All communication channels in Yugoslavia were controlled under the dictatorship and so were subject to being censored or even turned off. For this reason, the network had to provide high system redundancy.

Following the democratic changes in Serbia, the project's mission evolved into a suitable solution for a network of branch offices. The network involved broadcasters and correspondents from the six successor countries of the former Yugoslavia. In addition, correspondents from other networks were able to send their news packages and other information to ANEM.

The chapter consists of: a) the theoretical background related to the informing science framework and broadcasting business model, content life cycle and news production process, b) the case study, which describes specific informing environment, i.e. political, financial and technical constraints and c) the delivery system project including the organizational model, technical solutions and the analyses of the achieved results in two phases.

The Cohen's framework seen as Chapter 2 (Cohen, 1999) has been used to characterize the network system from an informing system perspective, starting with different levels of abstraction in information environment relating to the news production process, daily news production and news package through to the establishment a low budget delivery system for news distribution, supporting the goal of providing clients with true and accurate information.

Conceptual Overview

Technological changes have dramatically altered the way in which television programs are produced and distributed. Broadcasters and media producers are facing an enormous challenge. Video and audio compression methods, server technology and digital networking are all making a big impact on television production, post-production and distribution. Accompanying these technological changes are potential benefits of reduced cost, improved operating efficiencies and creativity, and increased marketability of material. Countering the potential benefits are threats of confusion, complexity, variable technical performance, and increased costs if not properly managed.

The competing interests of a variety of factors, such as audience, equipment manufacturers, content producers or advertisers, play significant roles in the process, and the area in which their interests converge is relatively small (Picard, 2000), as shown in Figure 1.

The pace of change in the television industry, as a result of the convergence of traditional broadcasting and information technology, is quickening dramatically as countries around the world make commitments to digital television broadcasting in one form or another. The result is the creation of many new, competitive, distribution channels that are driving a constantly-growing consumer demand for programming. Meeting that demand, in turn, requires a leveraging of the technologies used in digital signal processing, computers and data networking in order to yield significantly-enhanced creativity, improved efficiency, and economies of scale in the origination and dissemination of content.

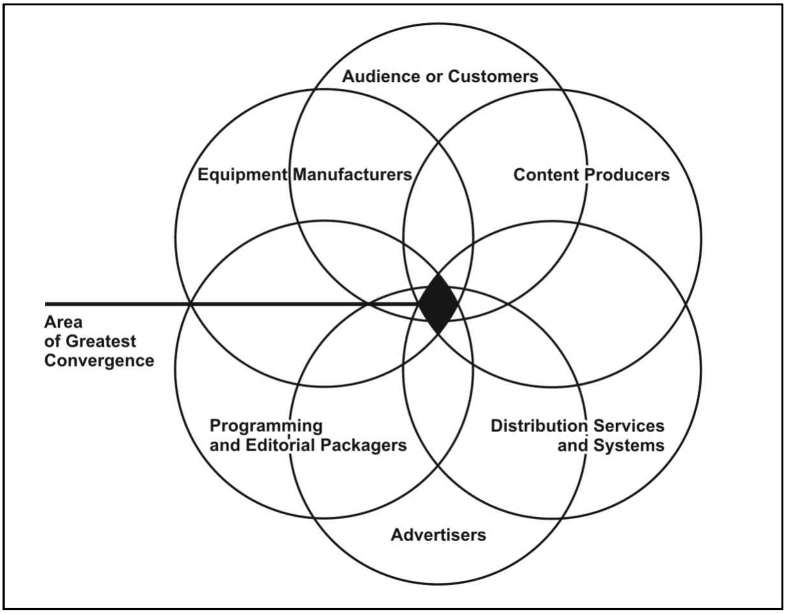

Figure 1: Convergence of interests, adopted from Picard (2000).

The production of television content, as well as whole broadcasting business, can be characterized using the Informing Science Framework, shown in Figure 2.

As Cohen (1999, p.8) stated, "the purpose of informing environment is to provide information to the client in a form, level of detail, and sequence to optimize the client's ability to benefit from that information". The particular production of news items, the daily news production process and general television news production represent the three levels of abstraction in informing environment: informing instance, instance creation and system design.

The design of an original delivery system that supports news contribution and distribution is the main topic of this case study. Low-budget multimedia technologies are used in this project to establish a system for production and the exchange of urgent news, with high redundancy and the ability to survive in a hostile political environment.

The core competence in the public broadcasting institution is to conduct the "broadcast mission" as a public service with strong democratic aims. Providing citizens (clients, in terms of Informing Science) with accurate and true information was the main **task** for this project.

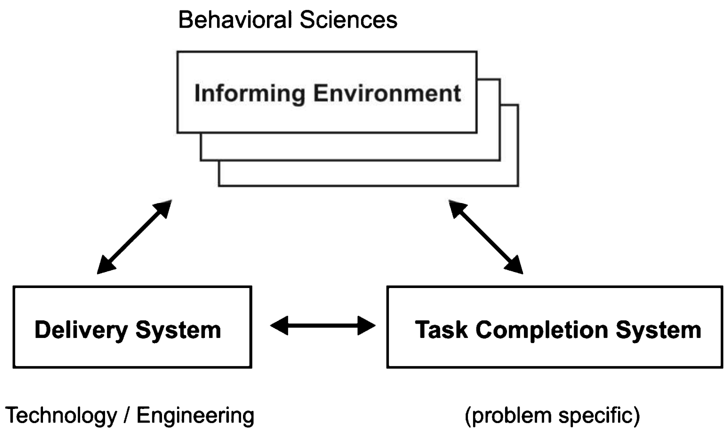

Figure 2: Informing Science Framework

Theoretical Background and Literature Review

Broadcasting Business Model and Value Chain Concept

Business models have been described as the architecture for the product, service, and information flows of a business unit, including a description of the various business activities and their roles. They include a description of the potential benefits for the various business actors and the sources of revenues (Timmers, 1998).

A business model embraces the concept of the value chain, that is, the value that is added to a product or service in each step of its acquisition, transformation, management, marketing and sales, and distribution. The value chain concept for products and services is now well established in business literature in which it was widely embraced after its exploration by Porter (1985). This value chain concept is particularly important in understanding market behaviour because it places the emphasis on the value created for the customer who ultimately makes consumption decisions.

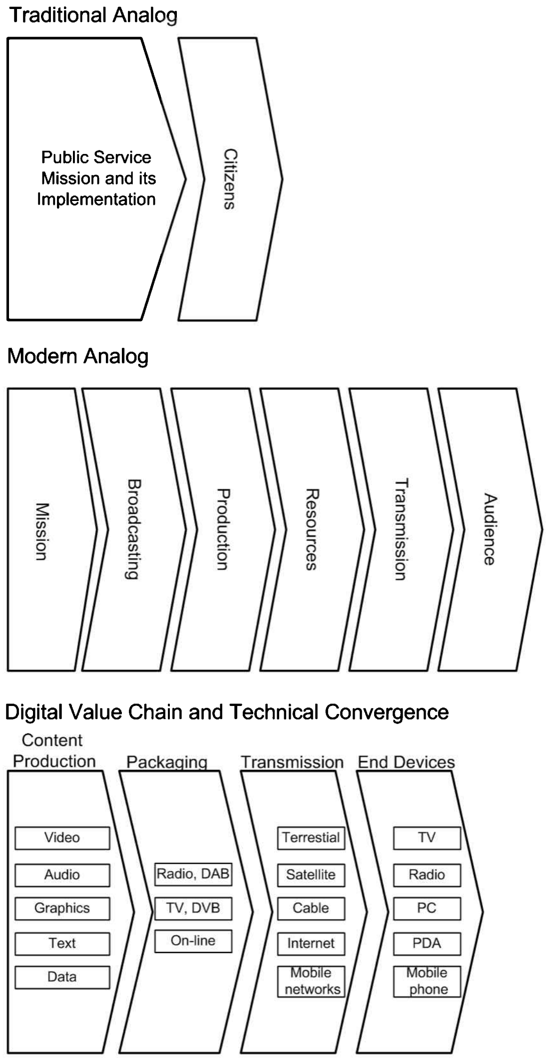

Figure 3: The value chain for broadcasting business

Alm & Lowe (2001) emphasized that in the traditional value chain the core competence in the (public) broadcasting institution is the (continuing) mandate to conduct the "broadcast mission" as a public service with strong democratic aims. Broadcasting business history between the late 1980s and the end of the 1990s featured a modernized version of an analogue value chain where the substantive work of corporate planning activities expressly coordinated the development of strategic programming goals with targeted resource allocation. The analogue era featured an approach based on controlling production. The associated management strategy separated programming activities, content production and resource functions.

The digital value chain emphasized its technological convergence, customer orientation and increased market competition (see Figure 3). This leads to an enterprise view based on functions and activities which add value, rather than on the organizational, historical or geographical factors which have traditionally governed broadcasters' choice of technology solutions. Abunu (2003) identified five distinct regions in the broadcast value chain: consumer, broadcasting, asset management, producing and business support.

Broadcasting Business and General Communication Model

According to Shannon and Weaver's model of the communication process (Shannon, 1948), also known as a general communication model, a message begins at an information source, which is relayed through a transmitter, and then sent via a signal towards the receiver. But before it reaches the receiver, the message must go through noise (sources of interference). Finally, the receiver must convey the message to its destination (Figure 4).

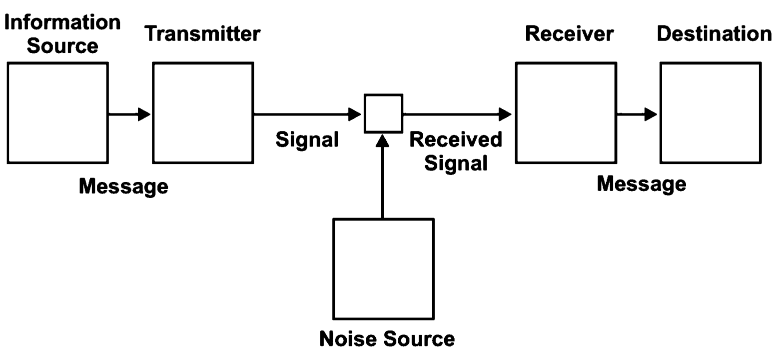

Figure 4: Shannon and Weaver's model of communication process

Shannon and Weaver's model purports to offer a neutral, objective way of talking about communication. But as the figure suggests, the model relies on a particular worldview, a scientific and mechanical version of communication and meaning. Not surprisingly, many people (in almost every field) have developed much more complex, socially situated models of the communication process that take into account the reader's role in the construction of meaning, the contingency of meaning, the context in which communication takes place, politics, and other factors. Shannon and Weaver in fact later refined their own model by introducing channels for feedback; more recent approaches have in turn provided more dynamic interaction loops—but the overall approach is still remarkably the same.

Rawolle (2000) suggested two categories of the transport media technologies: online or network-based technologies, and offline or portable storage media. All kinds of public networks are usually based on backbone-infrastructures. Relevant wired networks that can be used for the distribution of the media content are TV cable and Internet. On the other hand, wireless networks allow the transmission of content without having a physical link. Traditionally, the broadcasting industry have used terrestrial broadcast or satellites, which are both constrained to simplex transmission from sender to receiver. Offline media like CDs or DVD can be used to distribute digital content through traditional retailers.

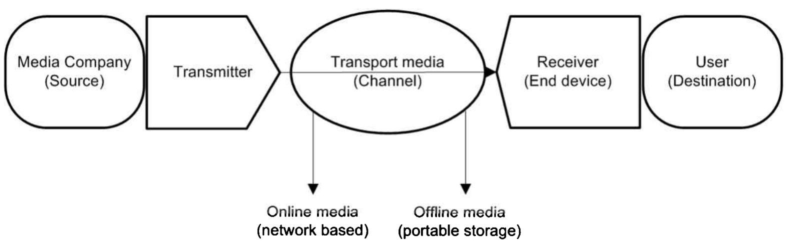

Figure 5: Model of content distribution represented as a simplified version of general communication model

desktop personal computers and television sets, and the convergence and consolidation of TV and PC in one console is already available. The main distinction between PCs and TV sets is user behaviour. PCs are typically used for retrieving and processing the information in an interactive way and TV is usually utilized in a more passive manner.

The media industry has recently shown considerable interest in mobile devices as new target devices. These can be divided into multipurpose devices like notebooks, sub-notebooks or personal digital assistants, and special purpose devices, such as mobile phones, e-books and MP3-players.

In the development of system management specifications, one must identify the difference between the "Push" and "Pull" models of content distribution, and understand the industry's movement toward the Pull model. The Push model refers to the process of broadcasting information from a source to passive receivers without an explicit request, while the Pull model refers to the process of a receiver requesting the information from a passive source. An example of the Push model is traditional television broadcasting, while the World Wide Web is an example of a Pull model.

The major difference for the content provider concerns the very different demands on timeliness, storage and distribution of the two models. The Push model gives a provider total control over the system resources. A successfully implemented system can allow for relatively limited demands on content storage and access, since distribution is straightforward and not dependent on audience size. Pull models, to be successful, must understand the scope of the demands that the audience will place on the content delivery mechanism.

Modelling the Life Cycle of the Content: State Machine Diagram

The traditional emphasis of the media business has been the creation, bundling and distribution of content consisting of information and entertainment. In publishing and media, content is information and experiences created by individuals, institutions and technology to benefit audiences in venues that they value (http://en.wikipedia.org/wiki/ Content).

The creation of the content that is of interest to users is the basic issue in the broadcasting business model. Advances in the development of interactive and multimedia technologies are increasing the number of producers and the availability of content and are forcing traditional media industries to develop new understanding of their roles in creating, processing and storing content.

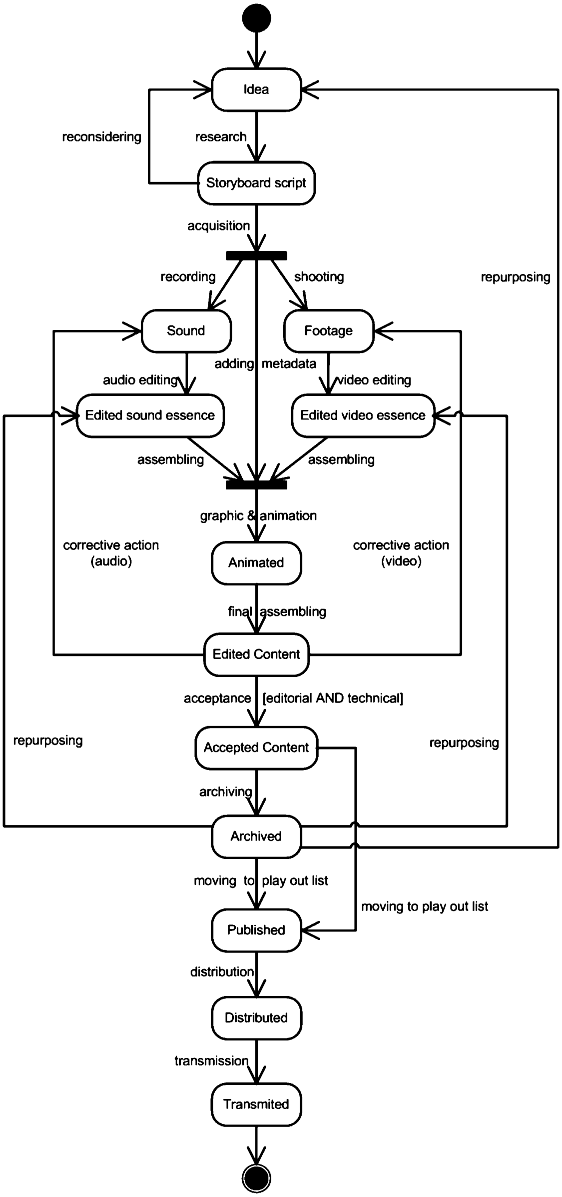

Figure 6: State Machine Diagram of Television Content Life Cycle

The nature of the state machine diagram is considered dynamic-behavioural. The state machine diagram of UML has the ability to represent time precisely and in a real-time fashion. "What happens at a certain point in time?" is a question that is answered by this diagram. Because of the dynamic nature of state machine diagrams, they are ideal for modelling real-time systems. These diagrams also show the entire behaviour of one object—depicting the life cycle of an object as it changes its state in response to the messages it receives. The state machine diagram representing the life cycle of the television multimedia content is shown in Figure 6.

Multimedia and Compression Techniques

Multimedia has long played an important role in the process of informing activities: learning, studying, researching, and communicating. Professional media activities, such as production of news, are based on creation and transfer of multimedia content. In accordance with Zeng and Yu (1999), a news package is a special form of multimedia data that can be managed in conformance with multimedia data management structure.

The delivery of multimedia information demands a large amount of channel bandwidth. This demand becomes one of the major driving forces for the development of new network infrastructure. Sharda (1999) presented fundamentals and future directions of multimedia networks, including multimedia transmission requirements.

Thomas and Storey (1999, p.1) anticipated that "changes in the way content is produced will be driven by blend of changes in the style of consumption and advances in technology" and emphasized MPEG-4 as a successful standard for video compression. Digital video compression is a field in which fundamental technologies were motivated and driven by practical applications so that they often lead to many useful advances. MPEG, the most recognized standard for digital video compression, has enabled many successful digital-video applications. These applications range from digital-video disk (DVD) and multimedia CDs on a desktop computer, to interactive digital cable television, to digital satellite networks. Nowadays, video compression technologies are being used in almost all modern digital video systems and networks. Not only is video compression equipment being implemented to increase the bandwidth efficiency of communication systems, but video compression also provides innovative solutions to many related video-networking problems.

There exist various compression techniques that are in part competitive and in part complementary. Many of these techniques are already applied in industries, while other methods are still undergoing development or are only partly realized. Most relevant work in the standardization bodies concerning video coding is outlined by Tang and Jin (2002).

The MPEG-4 architecture signified a major paradigm shift from earlier multimedia content representation standards. Much technical debate has focused on compression efficiency of the MPEG-4 video coder and, to a lesser extent, on the efficiency of the audio coder. Koenen (2002) presented information related to the efficiency of these coders. Also, Rittermann and Schuldt (2003) emphasized the benefits of MPEG-4 application system.

The authors of this paper have been in charge of "Project on the standardization of acquisition, information and communication systems in TV stations members of ANEM" (Nešić, Spasić, & Jovanović, 2000) which included the application of the above mentioned technologies.

News Production Process

Traditional Approach

Traditional production is based on analogue processes and expensive analogue components with no computers in the technological system, minimal using of the computers in the other parts of workflow and tape-based technological chain.

Segment production, in which primarily archival material is used to assemble the final program, has traditionally been characterized by organic workflows and extremely high quality output. It is built around analogue processes that depend on costly equipment located in expensive facilities. Media is edited and stored on magnetic tape, production tasks are strictly defined, and workflows are largely linear in nature.

Much of the same has been true for real time production environments although, in a nightly news or sports production studio, the production cycles are often razor thin. Material must be scripted, edited, and sent directly to air. Production systems in this environment are mission critical and, therefore, must be extremely stable and fault tolerant. Nonetheless, the workflows remain primarily linear and tape-based.

Hunter, Lau and White (2000) diagrammed simplified chain of production (see Figure 7).

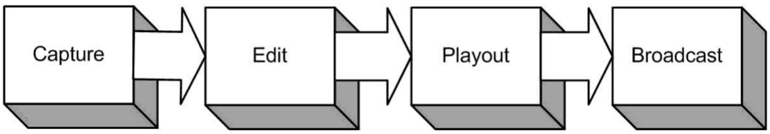

Figure 7: Simplified production chain

A news production process can be considered in a number of stages. A program's life begins with scheduling, research and planning. Video shots, audio clips and other programme items are created during the acquisition stage. In this stage, archived material is also checked for immediate suitability for re-purposing. Next stage is editing, when shots, clips, animations and assembled items are put in order. After editing, programme is sent to delivery point for transmission or play out. Finally, the program is archived on tapes.

Television programme production process can be characterized as a series of stages. Drewery and Riley (1999) outline such a simplified production process. At a very high level, the basic stages required to make and broadcast a programme are the same for all the constituent components, be it video, audio or presentation data.

New Model of News Production Process

New technology represents both an opportunity and a challenge to the traditional television production market. The last ten years have brought about some fundamental changes in the basic workflows and business models of content creation in the television industry. The dividing line between offline and online editing is starting to erode. The linear workflows of tape-based production are fragmenting. Producers can now perform multiple tasks in parallel including media creation, editing, and compositing. The sequence in which production and post-production tasks occur is less important than it used to be. As a result, there is really no longer any "post" in post-production. These changes are placing unprecedented strain on traditional production workflows. Many of these are beginning to collapse under the pressure.

The new model of production and post-production is based upon: digital formats, the centralized management of media and metadata, non-linear assembly of media elements, high-speed networks, format agnostic distribution and automated processes (locating footage, performing rough cuts, approvals, playout). Business processes are changed, each department is involved and processes are coming closer each other (Ebner, 2004).

As content is one of the most valuable assets for broadcasting companies, ingesting, archiving, accessing, managing, delivering and securing of digital content assets become basic requirements in the everyday life of multimedia producers and providers; at the same time, how the company structures its facilities, the processes involved and how it chooses the technologies that best adhere to the purpose related to content handling all become increasingly important. The new production processes are shown on Figure 8.

The basic production stages in this workflow are as follows: development, planning, acquisition, processing, control, archiving and publication. These stages are shown in Figure 8, including the production processes that are constituent parts of the stages. At each step in the production workflow we can collect, and possibly re-use the metadata.

A programme's life traditionally begins with a need to fill a slot in a schedule. A new skeleton schedule is first produced from the analyses of the audience numbers and reactions. This schedule has to encompass details of the programme categories, possibilities for re-using (repeat) of the programmes as well as outline budgets of the programmes required to fit into slots.

During the development stage, programme ideas are investigated and a commission is established when the producer persuades the TV company to finance the conversion of an idea into a real programme. The commission is very important for production as it gathers some key information like the 'working' title, producer's identity, contributor's names, genre and possibly initial scripts. It may also include financial decisions that subsequently apply to the rest of the programme making process.

When a commission has been accepted research was done and archives and other databases are examined for potential contributors, locations, facilities and material that can be re-used.

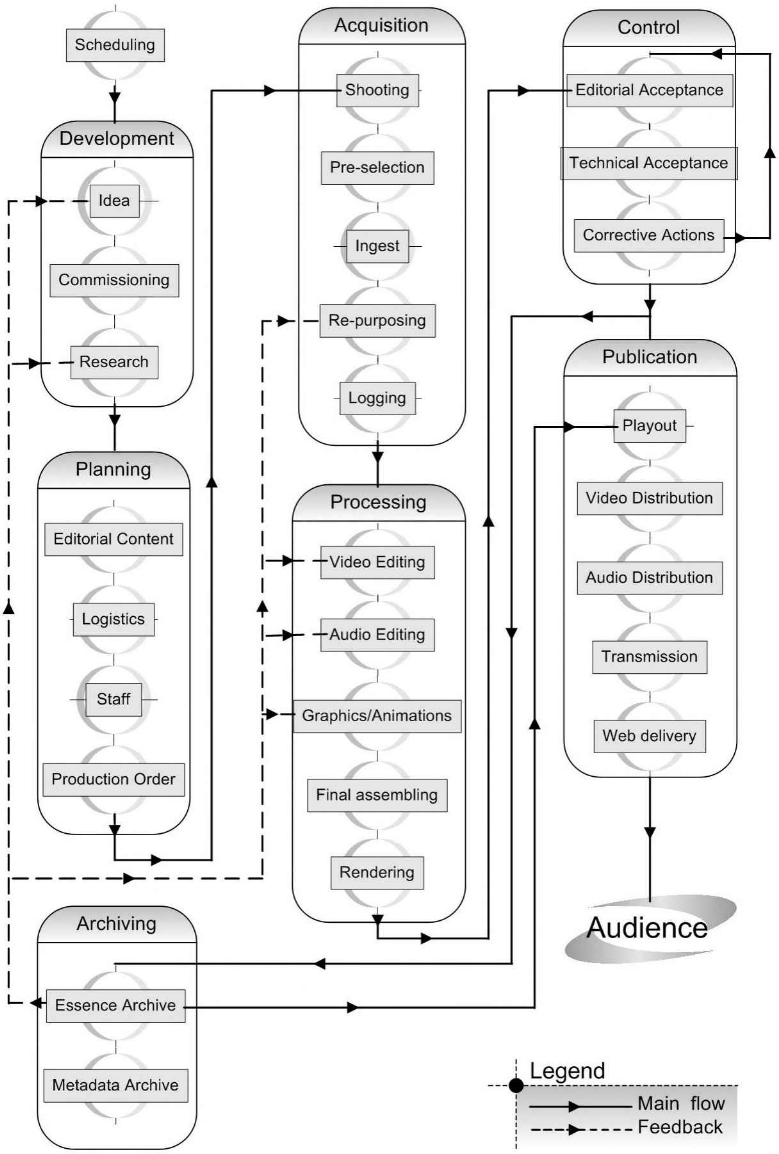

Figure 8: Programme Production Workflow

At the end of the planning stage a production order may be produced. The planning stage encompasses the staffing, resources and also the creation of the artistic description in the form of a storyboard and script.

During the acquisition stage, video shoots, audio clips and other programme items are created, pre-selected, ingested into production system and logged.

The obvious capture device is the camera, but equally, sound effects, graphics, stills, captions and music may all be added. At all points in capture there is an opportunity for metadata collection. Some of the metadata, like producer's comments and annotation, can only be captured by direct entry at the time of shooting. The metadata at this point in the chain should be viewed as 'portable', carried along with the essence as a link directly to a central.

The importance of the ingestion process is emphasized by Airola et al. (2002, p. 2) who noticed the following:

> *[the] crucial problem of Content Management Systems (CMS) is constituted by the ingestion of new content. As we cannot realistically expect that all the aspects of a production/archive environment are under the rules of a CMS, we need to set up gateways through which the content must pass when migrating from a non-managed environment to a CMS. The role of these gateways, that we call Ingestion Systems, is that of collecting and organizing as many relevant information (metadata) on the item as possible and that of generating all the content versions required by the CMS, including low resolution replicas of the essence, that can be exploited to economically implement browsing and offline editing functionalities, in such a way that time relations between the various versions are maintained. Selecting identical quality margins and algorithms for low resolution and for web publishing can bring further advantages and cost reductions. Automatic metadata capture and translation is also necessary to avoid lengthy and expensive manual processing.*

During the ingest, all the content collected during a shoot, as well as new metadata, is transferred into the production environment. The process assumes that planning and commissioning metadata is already in the system. More metadata can be generated at ingest and this can either be directly entered, for example by an operator marking technically poor sections or regions for special processing, or it can be extracted automatically.

Logging is where the producers review what they have, and mark down its possible use. It is expected that all the metadata capture that has taken place up until this stage will greatly reduce the overhead.

The processing stage represents a craftsman work where the shoots, clips, sounds and already assembled items are put into an order. The whole editing process, consisting of video and audio editing, has to be concentrated on capturing the composition metadata, the so called Edit Decision List, in order to accurately represent the artistic composition of the programme from its constituents. Different graphics, subtitling as well as animations are produced and added to the essence.

Editorial and technical acceptances, the constituent parts of the recurrent control stage, approve the use of the produced programme material. If corrections are needed, corrective action must be undertaken until editorial and/or technical approval is received.

Approved final product is catalogued and stored in archive. Archiving is one of the most important and most demanding organizational and technical processes in whole television production. Over time, media-rich organizations realized the value of their media assets. For instance, BBC Archive system has more than 750000 hours of television programmes in the archive, receives over 2000 inquiries each week and loans 45000 items per month (Evans, 2003). Archival system a usually consist of different servers such as workgroup media servers for short term storage and deep archive media servers for long term storage. Archival systems can contain and manage metadata archives, low resolution archives as well as archives of still images, effects, sounds and other media related data. Archiving in any form requires metadata to be captured, as the metadata is basis for a comprehensive search, and archiving is therefore a prime candidate for metadata re-use. The capture of metadata not only enhances the search, but also removes some of the overhead and uncertainty that archivists can have in cataloguing the material.

Publication is the last (but not least) stage in the new production workflow. Playout processes allow scheduled showing of the programme produced at earlier stages. Programmes, whether live or played from archive, are sent to a delivery point (transmitter chain, web etc.).

Case Introduction

Beginning in late 1980s, and formalized by the enactment of the restrictive Serbian Law on Public Information in 1998, the independent media in Serbia was suppressed, persecuted, harassed and attacked by the former Yugoslav government led by Slobodan Milosevic. Using tactics ranging from the bureaucratic takeover of media outlets and state-controlled broadcast-licensing competitions, to the brutal, still unsolved murder of independent newspaper editor Slavko Curuvija, the ruling regime created an environment hostile to the free press that alarmed human-rights groups around the world.

During this period, newspapers were seized, media outlets shut down and journalists murdered. In response, the Association of Independent Electronic Media (hereinafter ANEM), the largest non-government radio and television network in the former Federal Republic of Yugoslavia (later Serbia & Montenegro) decided to develop a system for exchanging news between TV stations, the members of ANEM. The normal method for exchanging information, using expensive digital microwave transmitters, was precluded by the regime, nor did ANEM's stations have the required financial resources to construct such a system.

The first decision of ANEM's management was to establish the Technical Committee – an expert body, intended to do research into the application of novel low-budget technologies to ANEM's stations. Several months before the Yugoslav federal elections on September 24, 2000, ANEM Technical Committee proposed a "Project on standardization of acquisition, information and communication systems in TV stations members of ANEM" (Nešić, Spasić, & Jovanović, 2000). The project proposed the application of digital standards for video acquisition, non-linear video editing and communications for use by the local TV stations members of ANEM. This project offered a suitable solution for the exchange of news described in this paper.

To estimate the importance of such a system, two aspects have to be considered. The first aspect related to the political constraints, since violent reactions of the regime against the media and citizens on the eve of democratic changes were real threat. Complete banning of free media and public rallies were expected. Such action of the regime would have caused dramatic events, including clashes of police with citizens resulting in a number of injured or even dead. Dark forebodings related to the anticipated total suspension of the freedom of thought, expression and the press encouraged the ANEM's management to prepare its stations for forthcoming events. The Technical Committee undertook the following assignment: establish a system for production and the exchange of urgent news, with high redundancy and capability to survive in a hostile political environment, using low-budget technical solutions.

The second important aspect was technical constraint. Basic user's demand was to provide production and reliable exchange of news packages in broadcast quality. In accordance with BBC news standard, the duration of each news package is approximately one minute and 45 seconds. Usual method for the exchange of video material between stations is using the network of expensive microwave transmitters, but a lack of funds in the independent media as well as the state-controlled licensing of transmitting equipment excluded this solution. Other technical possibilities had to be considered, and there was nothing left for the Technical Committee to do but to propose using public communication services. Unfortunately, these services were ruined during the long period of sanctions and NATO bombing, and nothing but the public telephone system was available. Thus, the requirement was highly challenging: achieve reliable exchange of high-quality video (i.e. large video files) through a devastated and state-controlled public telephone system, as fast as possible.

Because of constant financial constraints, the independent local and regional TV broadcasters had to use the production equipment of the customer instead of professional quality. That meant that the production chain, from camcorders up to the consumer delivery system, consisted of analogue components. Low budgets also implied low quality equipment, leading to low quality in the final programme products. That was a reason why the project proposed the application of digital standards for video acquisition, non-linear video editing and communications for the local TV stations members of ANEM. In addition, the former Yugoslavia had been under the sanctions of UN Security Council for more than 8 years, meaning that importing any professional equipment was a difficult task.

Nearly all the technologies applied in this project existed in infant forms. ISDN was mature, but it was available only in several cities in Serbia. DVCAM was declared a semi-professional standard for video-acquisition and its application in a professional environment was greeted with suspicion. The satellite internet connection service offered by Hughes Network Systems was expensive and it was proposed as a back-up solution. MPEG-4 was released in October 1998 as a draft international standard for the coding of audiovisual objects and it was aimed primarily at low bit rate video communications. During 1999 it went through several refinements and the application of MPEG-4 compression standard in this project became one of the earliest attempts to use it in a professional media environment.

Thanks to this system, the citizens of the biggest cities in Serbia had the opportunity to see the events that influenced the fall of Milosevic's regime and to participate in the "Serbian smooth revolution" that took place on October 5, 2000.

After democratic changes in Serbia, the system was re-designed and today it is the biggest network of news branch offices in South-Eastern Europe involving independent media and freelancers from five countries.

Restrictive Environment: Political, Organizational and Technical Issues

Political Constraints

By the year 2000, the independent media in Serbia – including radio and TV stations, printed media and other types of media agencies – had been systematically exposed to various forms of persecution, pressures, blackmail and threats ever since the late 1980s. The everyday situation of independent media staff had for thirteen years been marked by persecution, media takeovers and clampdowns and an exodus of journalists who were either dismissed or, on their own, decided to leave their media houses as they became propaganda offices of the regime. Threats, public accusations and harassment all became commonplace. Representatives of independent media grew accustomed to temporary arrests by the police, rigged trials, prison sentences, seizure of their private property and even murders.

The independent media, radio and TV stations, dailies, weeklies, magazines and agencies were the essential and the strongest, if not the only, segment of the democratic structure of the society. They also played an important cultural and educational role since their example demonstrated the use of the basic postulates of the modern world – the freedom of thought, expression and the press - and indicated the violation of human rights and the need to protect these as well as to create a market economy and an open society.

Despite considerable repression, the independent media in Serbia played a key role in informing electors of the choices facing them in the federal election of September 24, 2000 and in the run-up to the events of October 5.

Relevant Events Prior to "Serbian Smooth Revolution"

In order to convey the unfolding of the sequence of events pertaining to the "Serbian smooth revolution", extracts of the press coverage, presented in a chronological order, follow:

> **Sunday, September 24, 2000**
>
> The Yugoslav federation, which is comprised of Serbia and Montenegro, holds its presidential election. This is the first time for more than 7 million eligible voters to decide whether President Slobodan Milosevic and the Socialist Party stay in power or whether his 13-year rule comes to an end. However, monitors report several irregularities that point to the opposition's fear that Milosevic will rig the election to hold on to power. The country has already kicked foreign media out of the country, stopped international observers from monitoring the election and banned opposition representatives from many polling stations or from inspecting voters' lists. Both sides claim victory. The ruling Socialist Party says it has 44 per cent of the vote, compared to 41 per cent for the Democratic Opposition of Serbia, DOS. But the Opposition Leader Vojislav Kostunica says the DOS has captured 54 per cent of the vote, compared to 34 per cent for the government. Pre-election polls showed Milosevic trailing leading opposition candidate Kostunica. The counting of the ballots is suspended until Monday.
>
> **Monday, September 25, 2000**
>
> The opposition party claims victory despite the official release of the election results. About 40,000 people gather for a peaceful rally in Belgrade's main square to celebrate a victory for Kostunica and to say goodbye to Milosevic. The European

Union releases a statement saying any claim to victory by Milosevic would be fraudulent, believing Kostunica won 57 per cent of the vote compared to 33 per cent for Milosevic. But final results are still not known.

Tuesday, September 26, 2000

The Yugoslav Federal Electoral Commission says that preliminary results show Kostunica won 48.22 per cent of the votes, just short of the 50 per cent minimum required to win the presidency. According to election rules, if no candidate wins a majority, a run-off election must be held within 15 days. It's scheduled for October 8. But opposition organizers say Kostunica won 60 per cent of the vote and Milosevic has only about 35 per cent, based on results from 60 per cent of polling stations. Milosevic ignores the pressure and refuses to accept defeat.

Wednesday, September 27, 2000

About 200,000 people protest against Milosevic in Belgrade with banners reading "He is finished" and "Time to go." The opposition rejects the idea of holding a run-off vote believing Kostunica won a clear majority. With counting of the ballots complete, Yugoslavia's electoral commission releases the final results, showing Kostunica with 48.96 per cent of the votes and Milosevic with 38.62 per cent.

Thursday, September 28, 2000

Milosevic confirms that a run-off election will be scheduled for October 8. The opposition threatens to hold a general strike unless Milosevic gives up his claim to a run-off vote and admit defeat. Democratic Party leader Zoran Djindjic told citizens to join in a "total boycott, a peaceful general strike." More protests like the one held in Belgrade on Tuesday are expected.

Friday, September 29, 2000

Strikes in Yugoslavia shut down businesses, coal mines and television broadcasts. Hundreds of taxi drivers blocked roads and bridges, and thousands of high school students walked out of class. The opposition files an official complaint with the

Federal Election Commission and promise to take their fight to court if Kostunica isn't declared a winner.

Saturday, September 30, 2000

The Federal Election Commission rejects complaints made by the opposition. Disruptions continue with truckers shutting down an oil refinery by parking outside its main gates. Another rally is held in Belgrade. The opposition calls for a general strike on Monday.

Sunday, October 1, 2000

Russia releases a joint statement with Germany declaring "the will of the Serbian people in Yugoslavia had been clearly expressed" in the September 24 election. The statement is a clear call for Milosevic to step down. In an attempt to resolve the political crisis in Yugoslavia, Russia also sends in two envoys into Belgrade for talks.

Monday, October 2, 2000

Milosevic accuses the opposition of resorting to bribes and blackmail and says it is being controlled by NATO and Western countries. Truckers and taxi drivers slow traffic to a halt in several cities across the country by blockading roads and bridges. Walkouts at two important coal mines and an oil refinery have caused worries about the power and fuel supplies. Thousands of workers have left key industries such as railway lines idle. So far, Milosevic has not used either the military or the police to quiet calls for his departure.

Tuesday, October 3, 2000

The Milosevic government orders the arrest of 11 striking miners and two opposition leaders on suspicion of sabotage. The shut down of coal mines that supply power plants has left many parts of Serbia without electricity. The miners refused to go back to work after meeting with Yugoslavia's military chief of staff.

About 50,000 students march toward Milosevic's official residence in the suburb of Dedinje but riot police convince them to return to the centre of Belgrade. The government promises to take "special measures" against organizers involved in criminal activities.

Wednesday, October 4, 2000

Yugoslavia's highest court invalidates parts of the election although details as to which parts are annulled are not released. Kostunica warns the move may be "a big trap." If parts of the election must be repeated, it would buy Milosevic more time. Police take over key parts of a coal mining complex after attempting to break up the strike there, but miners and more than 10,000 supporters remain there. People begin to gather in Belgrade for a rally planned for tomorrow. The rally is expected to draw more than one million people.

Thursday, October 5, 2000

Dozens of people are injured in Belgrade as police and protesters fight with bullets, tear gas, batons and rocks. Protesters manage to storm several government offices, capture the state-run media and set fire to the parliament building. They destroy furniture and computers and throw pictures of Milosevic out the windows. Celebrations break out with singing and dancing in the streets after the police retreat from the area. Busloads of supporters arrive from across the country to join the mass rally. Now controlled by the opposition, news agencies declare Kostunica president. The opposition leader addresses the crowds, asking them to calm but remain in the streets overnight. Kostunica also calls for a meeting with military leaders and says a new federal parliament will convene Saturday. The news agencies reporting soldiers are staying in their quarters, refusing to take sides in the battle for power.

Friday, October 6, 2000

The European Union announces it will begin lifting international sanctions against Yugoslavia on Monday. Russian Foreign Minister Igor Ivanov meets with Milosevic at his official residence in Belgrade. Ivanov says Milosevic wants to continue playing a political role through his party. But both Russia and Milosevic's socialist allies in Montenegro have recently acknowledged Kostunica's September 24 election

> victory. Celebrations continue outside the legislative building in Belgrade. Kostunica meets with the army chief of staff Lieutenant General Nebojsa Pavkovic on Friday and had a one-hour conversation with Milosevic. He announces the people have nothing to fear of the army. Kostunica is set to be inaugurated on Saturday.

The ANEM Story

The Association of the Independent Electronic Media (ANEM) is a business association comprised of 28 radio stations and 16 television companies as well as of more than 60 affiliated organizations. ANEM was founded in 1993, and in 1997 it became a registered company in accordance with the Serbian Law on Companies.

According to the quantity of programme and service zones, ANEM members are big and small stations, local and regional. Common to all of them is news broadcast programme that strives to achieve the highest professional standards. After October 5, 2000, around 100 radio and TV stations applied for membership into Association and some of them became affiliate members. Radio ANEM covers 60% of the territory of Serbia and 70% of the population. TV ANEM covers 35% of the territory of Serbia and 50% of the population.

The mission of ANEM is to establish a politically independent legal framework and an economically viable environment for the development of electronic media, and improvement of the professional and technical standards in the media sphere in order to meet the needs of the audience and serve the public interest in a proper way. During the ruling of Slobodan Milosevic ANEM was the fortress of Serbian independent journalism. Mainly consisting of radio and TV broadcasters owned by municipal authorities in biggest cities where democratic opposition had some power, ANEM organizationally was a network of independent electronic media.

Technical Constraints

Communication infrastructure in Serbia, especially public switched telephony system and terrestrial wireless systems, was significantly damaged by the long period of economic sanctions - from 1992 up to 2000 - and NATO air strikes in 1999. The poor quality of public communication services was a major technical obstacle in the realization of system for exchange of news packages. The Integrated Services Digital Network (ISDN) connections in some cities were the best communication service available during that time period.

ISDN was designed in the 1980s to provide data rates in the range of Kbps to Mbps over switched connections. To provide even higher data rates the original ISDN was extended to Broadband-ISDN (B-ISDN). The ISDN services are provided to the user as ISDN interfaces, where each interface comprises a number of ISDN channels. ISDN channels, their bandwidths, and application areas are listed in Table 1 (Beyda, 1996, p. 211). These channels are combined to provide standard interfaces called: Basic Rate Interface (BRI), Primary Rate Interface (PRI), and Hybrid Interface. The various ISDN interfaces are listed in Table 2.

Table 1: ISDN Channels

Channel Designation	Channel Type	Bandwidth	Application area
A	Analog	3-4 KHz	Analog voice
B	Digital	64 Kbps	Digitized voice and data
C	Digital	< 16 Kbps	Low speed data
D	Digital	16 or 64 Kbps	Signaling or data

Table 2: ISDN Interfaces

Interface Name	Channels	Combined Bandwidth	Application area
Basic-rate interface	2B+D	144-192 Kbps	Digitized voice and data
Primary-rate interface	23B+D or 30B+D	1.544 Mbps or 2.048 Mbps	Multimedia including video. LAN to LAN connection
Hybrid interface	A+C	Analog voice + 16 Kbps data	Hybrid connection for transition period

TV stations that participated in the first phase of this project were located in the biggest cities in Serbia and they were selected based upon the availability of ISDN connections in their cities. Also, the quality of

Internet service providers (ISP) in these cities was considered as an important issue.

Basic-rate interface ISDN was the only acceptable connection available during that period. The BRI interface is aimed at providing a simple interface to the desktop that includes a phone connection and a digital interface for the desktop computer. The D-channel is used for signalling; and the two B-channels provide a bandwidth of 128 Kbps for data transmission.

Despite the conclusion that "the bandwidth of the BRI interface falls short for any serious multimedia application it is barely enough for low-end video conferencing" (Sharda, 1999, p.16), the authors of project had no other solution for communications.

Choice of Standardized Compression Format

The bandwidth required for a video signal in standard definition television is approx. 150 Mbps. Full format assumes horizontal resolution with 720 lines, vertical resolution with 576 lines and 25 frames per second. It is obviously that compression techniques had to be implemented on edited news package before the process of exchange starts.

The compression standard suggested for standard definition television was MPEG-2 (Sharda, 1999, p.12). MPEG-2 is a non-proprietary format that had been originally developed for transmission purposes, and is used by all new digital services, as well as DVD. Because MPEG-2 allows the use of motion-compensated prediction, quite high compression ratios can be used. This makes MPEG-2 attractive for archiving and play-out because of server and LAN bandwidths could be reduced.

Unfortunately, the BRI ISDN connection available in Serbia in the middle of 2000 meant that higher compression ratios than MPEG-2 had to be implemented. Thus, the application of MPEG-4 software compression was proposed as a solution.

MPEG-4 passed in 1998 as a standard for the coding of audiovisual objects. The "Moving Pictures Expert Group" is a working group of the International Organization for Standardization (ISO). Version 1 of MPEG-4 was approved in October 1998 and version 2 in December

1999. Three amendments to MPEG-4 Video have been published in 1999 and 2001.

In the early 1990s, MPEG-1 and MPEG-2 became two very successful standards for coding video with associated audio. MPEG-4 went far beyond being an incremental improvement of MPEG-2, however.

Novel approaches to coding audio and visual content were defined. The most important feature of MPEG-4, compared with MPEG-2, is a higher compression ratio, which implies the lower size of news package file and a shorter transmission period. The other important features of MPEG-4, which influenced choice of this standard as a data format suitable for the exchange of news packages, are the ability to efficiently encode mixed media data such as video, graphics, text, images, audio and speech, and error resilience to enable robust transmission of compressed data over noisy communication channels.

Initially, MPEG-4 was aimed primarily at low bit rate video communications. However, its scope was later expanded, and it became much more than a multimedia coding standard. MPEG-4 is efficient across a wide variety of bit rates ranging from a few Kbps to tens of Mbps (Liang, 1999, p.102). In addition to providing improved coding efficiency, MPEG-4 also provides a number of functionalities. Unlike MPEG-1 and MPEG-2, that were designed and, at least in the first phase, to be implemented as traditional hardware solutions, MPEG-4 was conceived as a standard whose implementation could be software.

Project Overview

System Overview: Phase I

The system established in the first phase consisted of 8 completely configured workstations located in biggest stations members of ANEM. Each workstation had to provide autonomous work in video acquisition, non-linear digital video editing and the exchanging of news.

The locations and the list of participating stations are shown in Figure 9 and Table 3.

The parts of each workstation were the digital systems for collecting video information and non-linear digital video editing and systems for communications.

Figure 9: Locations of TV stations

Table 3: Participating TV stations in the first phase

TV Station	Location	Distance (km)	Connection type
ANEM Central Office	Belgrade	-	DSL, ISDN
TV Nis	Nis	240	ISDN/DSL
TV Kragujevac	Kragujevac	140	ISDN
TV 5	Uzice	180	ISDN
TV Cacak	Cacak	140	ISDN
TV Kraljevo	Kraljevo	170	ISDN
TV Trstenik	Trstenik	210	ISDN
TV Pirot	Pirot	310	ISDN

The workstation consisted of the digital camcorder, digital tape, preview monitor, specially configured PC-based computer, a satellite antenna with a low-noise converter, ISDN public network connection and cabling. The heart of the workstation is a PC-based computer equipped with a non-linear digital video editing adapter card, a DirecPC™ adapter card for satellite internet connection and an ISDN network adapter. The workstation's block diagram is shown in Figure 10.

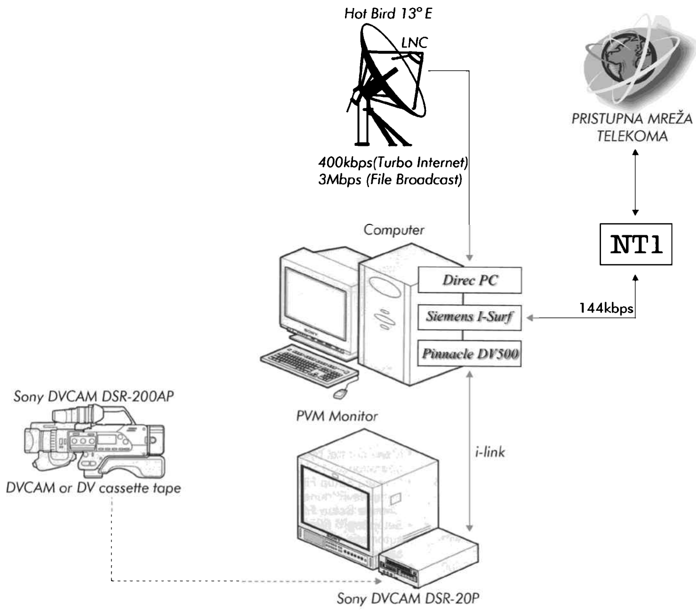

Figure 10: A Workstation for Acquisition, NLDVE & Communication

Package Contribution Methodology

The news editing and package contribution methodology was as follows:

- Video information collected by the ENG team is transferred to the computer by FireWire (i-Link, IEEE 1394).
- Non-linear digital video editing (NLDVE) is made using the Pinnacle miro DV 500 adapter card and the suitable software (Adobe Premier).

- The package is compressed using the MPEG-4 software compressor.
- Public ISDN services and File Transfer Protocol are used for the transmission of the news package from the workstation station to the FTP Server computer located in the ANEM's Central Office.

The redundancy of the contribution subsystem is provided by the fact that the edited package can be sent from any computer equipped with the ISDN adapter to any FTP server.

Package Distribution Methodology

The package distribution methodology was as follows:

The satellite up-link station received the packages from an FTP server computer located on the ANEM's Central Office by the DirecPC™ adapter card which supports throughput up to 400 kbps in Turbo Internet mode or 3 Mbps in File Broadcast mode.

All the TV stations, the members of ANEM, can receive all available news packages by using open satellite service from ANEM's digital channel located on satellite EUTELSAT 36° E.

Among other things, participated stations can use its own DirecPC™ system for receiving many packages from FTP server in ANEM Central Office if the open satellite service or satellite up-link station is not functional. Use of this system was expensive, and it was a back-up system for package distribution.

It is assumed that each TV station can use its own ISDN connection for receiving the single package from the central FTP server.

Also, the TV stations can communicate directly, providing the horizontal redundancy of the system. Package distribution system overview is shown in Figure 11.

Two satellite services, internet service providers (ISP) and public ISDN and HDSL services were combined for realization of package distribution methodology described above.

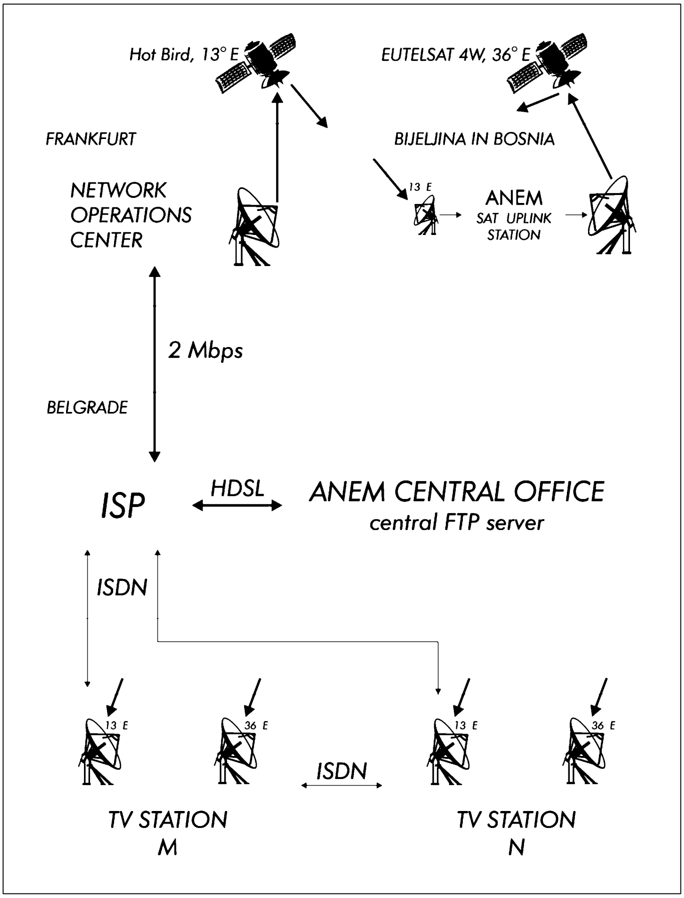

Figure 11: Package Distribution System Overview

Results in the First Phase

A series of experiments with different resolutions and bit rates were conducted.

When the full quality of video material was requested, with standard horizontal and vertical resolution and frame rate, the duration of compression needed for one minute of the video material was approximately 4 minutes. One minute of such video material could be transmitted in approximately 33 minutes. The quality of decompressed video material was quite acceptable for play-out.

In cases where a horizontal resolution of 384 lines and vertical resolution of 288 lines was used, one minute of the video material could be transmitted in approximately 10 minutes. The quality of decompressed video material was comparable with standard VHS video. This format was used when urgent news packages had to be transmitted, and lower transmission time was important.

System Overview: Phase II

The system was redesigned after the democratic changes in Serbia. Television B92 was established, the biggest and the most influential member of ANEM located in Belgrade, with national terrestrial and satellite coverage. The system today represents a network of news

Figure 12: Branch Offices – Present Situation

branch offices from local TV broadcasters in the biggest regional community centres in Serbia, as well as stations and branch offices from 6 neighbouring countries to Radio Television B92. The locations and list of participating stations is shown on Figure 12 and Table 4.

Table 4: Participating TV stations in second phase

TV Station	Location
1. B92 (main)	Belgrade, Serbia
2. TV Niš	Niš, Serbia
3. TV Kragujevac	Kragujevac, Serbia
4. TV 5	Užice, Serbia
5. TV Čačak	Čačak, Serbia
6. TV Kraljevo	Kraljevo, Serbia
7. TV Trstenik	Trstenik, Serbia
8. TV Pirot	Pirot, Serbia
9. TV Valjevo	Valjevo, Serbia
10. TV Požega	Požega, Serbia
11. TV Grk	Prokuplje, Serbia
12. Branch Office Niš	Niš, Serbia
13. RTV Kojot	Zrenjanin, Serbia
14. Glas juga	Gračanica, Serbia
15. TV Podgorica	Podgorica, Montenegro
16. NTV Montena	Podgorica, Montenegro
17. PG Urbans	Novi Sad, Serbia
18. TV Skoplje	Skoplje, FYR Macedonia
19. RTL Zagreb	Zagreb, Croatia
20. CCN, 7 stations	Croatia
21. VOA (Voice of America)	Washington, USA

The improvement of communication infrastructure in Serbia is in progress, offering new opportunities for exchanging of news packages and other multimedia content between stations in network. These opportunities include cable broadband, different DSL and wireless communications.

Thanks to hardware and software improvements, the duration of compression needed for one minute of the video material is today approximately one minute and 10 seconds. Currently, one minute of the compressed video material can be transmitted in approximately. 21 minutes over an ISDN connection, or about 2 minutes over a DSL connection.

It is obvious that a news package can be sent from any point on the globe with an Internet connection and a suitable workstation. That is the reason why the system is easy to expand, and the future development of the system must consider that fact. With the growth of the system, the managing of news packages on the server will become a serious problem, and the development of content management workflow, as well as suitable software, therefore become the next critical task.

News Branch Office in Niš: An Example

The corresponding branch office in Niš is a successor of offices established in the first phase of project. This office is the biggest and most important in the whole network at this time.

Niš is the second largest city in Serbia, and the centre of the Administrative District of the Nišava. Situated at the crossroads, Niš connects the Balkans to Europe, and Europe to the Near East. As a traffic crossroad of European roads and railroads, together with an airport, it can easily be reached from all directions. Niš is a university centre, and a city of more than 350 000 inhabitants. It is the centre of the whole south-eastern part of Serbia - the natural, social, economic, educational, medical, cultural, and sports centre. The city covers the area of about 597 square kilometres, including the city of Niš itself, the Niška Banja spa and 68 suburbs. Among other things, it is one of the most important industrial centres in Serbia.

The service zone of Branch office Niš consists of seven administrative districts located in southern and eastern Serbia with 1 600 000 inhabitants (see Figure 13). These districts are close to the possible sources of urgent information such as UN Security Zone in Kosovo (southern part of Serbia) or border crossings. The terrestrial covering of TV B92 is about 1 200 000 inhabitants in same area.

In addition to television news, the Branch office in Niš is capable of producing radio news packages, interviews, documentary production as well as news for the internet site of B92 (www.b92.net).

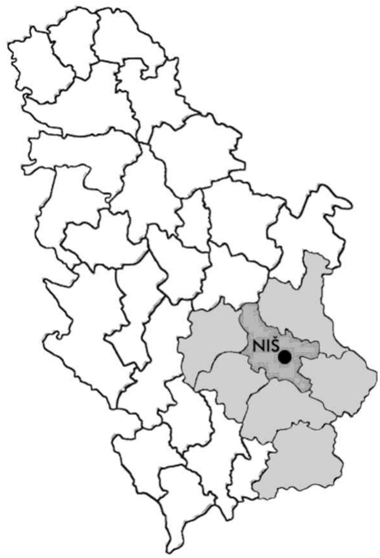

Figure 13: Office Niš Service Zone

The branch office crew consists of one journalist and one technical operator. The journalist is responsible for planning and scripting package, disposition and presenting. The operator is responsible for shooting in the field, ingesting raw material into the editing computer, picture and sound editing, final processing and transfer to a server located in TV B92. The start-time of the crew is 30 minutes. The time needed for shooting is approx. 2 hours, and the additional 45 minutes are necessary for non-linear editing. That means that one package can be produced for approx. 3 hours and 45 minutes, including 30 minutes for transferring to the server. If the shooting location is outside of city of Niš, the time for two-way transportation must be added.

The Branch office in Niš is based on digital standards and represents an upgraded component of the previously described system. This upgrade is shown in the ability of faster sending and better quality of produced news packages.

Since B92 accepted DVCAM as a standard for news production, the Branch office in Niš has the equipment based on this standard. The equipment for non-linear digital video editing is based on the accelerator card Canopus DVStorm2 Pro.

The cable broadband communication is used for transferring the news packages and throughput is no less than 512 Kbps. The quality of communication channel made possible the exchange of news packages in full broadcast quality. The requirement for such quality assumes using of MPEG-2 compression and the bit rate of 6 Mbps. A file with one minute of compressed news material is approx. 45 MB in size, and one news package is in average 80 MB in size. The time needed for transmission of such package is approx. 22 minutes.

In situations when urgent news has to be exchanged, MPEG-4 compression would be used. In this case, one minute of news package is approx. 20 MB in size. The news package is in average 35 MB, and time needed for transmission is approx. 10 minutes.

The Branch office in Niš has existed for one year, and this concept of branch office demonstrates that the presented system is economically viable and stable for use in the production of daily news.

Conclusion

The Metcalfe's law states that the value of a communication system grows approximately as the square of the number of users of the system (N^2). Since a single user cannot connect to itself, the actual calculation is $N(N-1)$, or N^2-N. First formulated by Robert Metcalfe in regard to Ethernet, the Metcalfe's law explains many of the network effects of communication technologies and networks such as the Internet and World Wide Web.

Brinkman and Flank (2002, p.2) paraphrased the Metcalfe's law and stated that “the value of any media asset increases by the factor of the number of people with access to it.” In addition to the above mentioned conclusion, the value of the news media asset in a professional media environment has another dimension – the delivery time. One of the most important advantages possessed by the low-budget television is the ability to be on the field where and when important events happen. This advantage increases in accordance with the Metcalfe’s law if the functional and high-effective network of low-budget station is already established. The contemporary multimedia solutions give the opportunities for building such an inexpensive network.

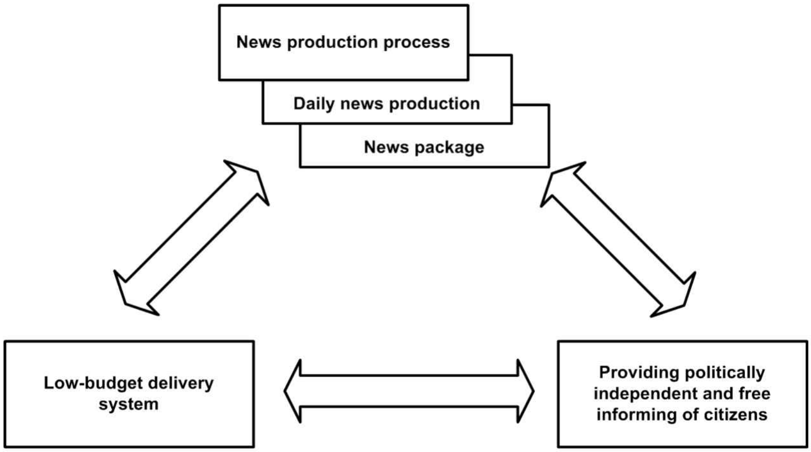

Figure 14: Informing Science Framework – Project Context

The project described can be characterized using the Informing Science Framework, with the Informing Environment, Delivery System and Task Completion as specifically represented in Figure 14. It illustrates a number interesting aspects of informing systems that include:

1. The use of a particular delivery system to support several different informing systems. There is considerable irony associated with the fact that technologies provided through the state-controlled telephone system also served as delivery systems for the very news content that ultimately undermined the repressive regime state and led to its downfall. This may not be as unusual as it first appears. By the aforementioned Metcalfe's law, if the state wants to magnify its control through use of a particular channel, such as the telephone system, it must ensure its citizens attend to the channel. That means allowing the channel to be employed for other purposes, such as private conversations and commerce, which—in turn—means that the capabilities of the channel need to be adequate. That very need to keep the channel active and available for other uses means that informing systems that the state does

not wish to encourage, such as the ANEM system, are very hard to suppress. This grows increasingly true as technology allows us to encode our messages in a form that makes them suitable for a variety of channels—even relatively low bandwidth ones.

2. The impact of delivery system and channel properties on informing processes. As noted in the case, the introduction of digital video and compression standards dramatically changed how content was collected, modified, archived and distributed. Indeed, virtually every activity in the production process was transformed. We must therefore be very careful not to treat the elements of the informing process (e.g., Figures 4 and 5) as being independent. While such a conceptualization helps us understand the roles required for informing, the degree of interaction between them is enormous. For an informing system to remain efficient, any changes to one component of the system will likely entail modifications to the remaining components.

3. Success in informing ultimately motivates continuing transformation of the informing system. In the case described, we see that the ANEM informing system—whose principal motivation was to provide an effective independent voice to counter a repressive regime—materially contributed to the downfall of that regime. In doing so, however, they dramatically changed the constraints under which they operated, leading them to further transformative changes to increase their fit with the new environment. It may well be that a system's success in its informing activities necessarily encourages such subsequent transformation. What makes informing systems different from communications systems in general is that they seek to alter a client's mental models. If successful in doing so, the system has—effectively—changed the client. In many cases, the informing system most appropriate for informing the "changed" client may be different from the original system.

After the democratic changes in Serbia, the system today represents the biggest network of corresponding offices and television stations in South-Eastern Europe. The challenge for the future is to make this system economically viable and stable for use in volume TV production. The incremental growth of the system and involving other ANEM stations and corresponding offices from different countries offers new possibilities in informing citizens. With the growth of the system, managing of news packages on the server will become a serious problem, and the development of content management workflow, as well as suitable software, have to be the next task. Due to this need, a web-based content management system is planned for development. Designing the system for management and the production of metadata related on video material can make possible a strategy for the effective management of news media products and the data associated with them throughout their lifecycle. Changes in how clients prefer to acquire their news, such as through the web or social networking sites, will doubtless require continuing changes to the system.

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Chapter 18

Cyberdating: (Dis)information and (Dis)trust in Online Interaction

Xin-An Lu and Hong Wang

Introduction

The Internet has become an important alternative venue for romantic ventures. "Cyberdating," as it is called, offers new possibilities for creative interactions not found in the real-life world. The fact that Internet dating and matching services have grown from $398 million in 2004 to $642 million in 2008 (Reuters, 2004) attests to the popularity of cyberdating. This popularity may be attributable to the Internet's flexible accessibility, large pool of potential partners, and perhaps most importantly, anonymity–with the new freedoms attending that anonymity. These freedoms remove and disentangle netizens from the moral and social qualms in the face-to-face world and facilitate a "free play" with identity and imagination.

With the new possibilities of cyberdating come problems deriving from the characteristics of this new arena for romance. Disinformation, for instance, has proven to be a troubling phenomenon in cyberdating, whose dangers and treacherous nature have been plentifully covered in the popular press. Scan the following headlines: "When spouses go astray online"; "Man with over 200 online wives"; "Internet romance ends with man jailed in Wales"; and "French woman dies after an Internet romance sours." We also hear of more dramatic tragedies in cyberdating that involve kidnapping, abuse, and even murder. The cost for cyberdating can be huge--emotionally, physiologically, socially, and economically--thus warranting scholarly study.

This chapter begins by explaining how the study of cyberdating fits into Cohen's (2009) model of Informing Science which is reprinted here as Chapter 23. It next offers an analysis of the media characteristics of cyber space that tend to render information more malleable and the incidence of disinformation more likely. This is followed by an examination of the dual nature of online interaction: disinformation at the Sender's end and (dis)trust at the Receiver's end. We then consider how trust is gained and lost in cyberdating. What principles and behaviors affect the operation of trust in cyberdating? Do online encounters commence with assumed trust or must trust be acquired in the process of deepened interactions? A reported case of fraud in cyberdating is then considered to both illustrate and analyze the process of disinformation detection. The chapter concludes with some practical implications for cyberdaters and their relationship development.

Cyberdating in Cohen's Framework for Informing Science

As an informational transaction between and among human agents, cyberdating follows Cohen's framework for studies of Informing Science. As laid out in his works published in 1999 and 2009 (Chapter 2 and 23 of this book), Informing Science includes the following major components: the informer, the client, the need or task to be fulfilled, the delivery system for the transacted information, and the context or environment of the informational transaction. Cyberdating, as a unique type of mediated informational transaction, clearly falls into Cohen's framework (see Figure 5 in Chapter 23).

Each of the components of Cohen's framework comes into play in cyberdating. A need or task is involved, serving to motivate the cyberdater to initiate cyberdating, typically the desire to find a marital partner or soul mate. An informer produces and delivers information– the messages that form the basis of cyberdating communication. The targeted client similarly receives these messages. The cyberdating site typically provides the message delivery system, employing Internet-based technologies such as email and chat. A cyberdater, in order to be effective in his/her endeavor, cannot ignore the context and environment, since all of these can potentially affect the reception, the perception, the interpretation, and ultimately, the behavior of the client receiving the messages.

The study of cyberdating does diverge from Cohen's simplified model of informer-client interactions in some important respects. Most importantly, the distinction between informer and client is problematic. Much of the informing that takes place in cyberdating is reciprocal, meaning that the informer and the client roles are fluid and interchangeable. We would anticipate that such reciprocal informing may be encountered in many peer-to-peer contexts, such as social networking sites and even in settings where informer and client roles are more clearly defined, such as a doctor's interaction with a patient.

Another difference from the original Cohen model involves making a clear distinction between "context" and "environment." Conceptually, the scope of "context" is smaller than that of "environment"--the former being personal in its scope while the latter can be viewed as societal. This distinction is necessary as the personal context and the societal environment of the communication agents may be distinct from each other. The informer and client may exist in the same societal environment but have very different personal contexts. Thus what affects the behaviors of information delivery and reception is not the broader societal environment, but the more local personal context. The reverse case may also be true, however, when individuals with similar personal values and needs come from different cultures or different societal environments.

We also believe it makes sense to refine the concepts of "context" and "environment" by sampling prominent factors in those two concepts. The personal context of the communicator includes factors of time (temporal), space (spatial), desire (volitional), technology (technological), all of which affect communicational behavior. The societal context of "environment" includes the prominent factors of culture, ethnicity, religion, and government. These are illustrated in Figure 1.

We also employ the hyphenated word "trans-formation" in the revised model. This hyphenated word is to remind the informer/client that information, in the process of transaction, mediated by various contextual and environmental factors (as enumerated in previous point) on the two sides of the transaction, frequently is *trans*lated and *trans*formed, leading to misinformation and disinformation. Contextual and environmental factors can also engender human fragility (see Chapter 23), another factor contributing to mis- and dis-information.

Finally, as shown beneath "transformation" in Figure 1, the communicational results of the informing process may be characterized in terms of affinity or antipathy. The greater the congruence between the delivered and received versions of the information, the greater the affinity expected between the two sides, encouraging intensified future communications. When substantial incongruence exists between the delivered information and the received information, antipathy is produced, leading to reduced communication rates, or even to conflict, in the future. Achieving affinity can become a complex task when various contextual and environmental factors and the factor of human fragility are involved.

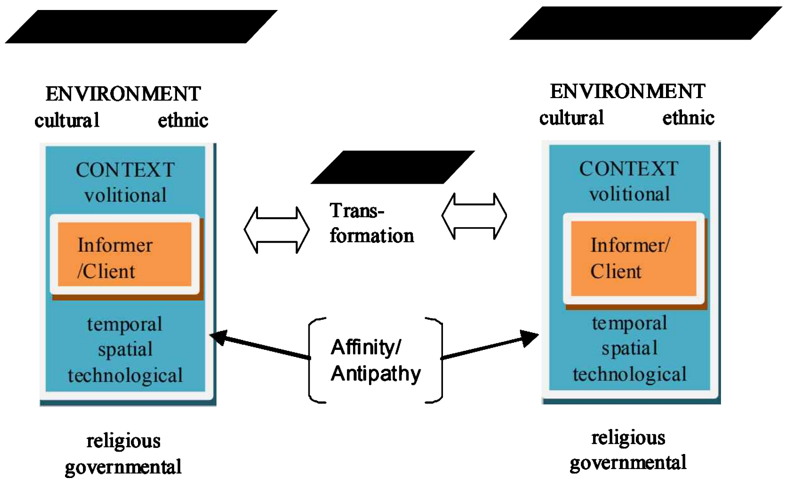

Figure 1 Expansion of Cohen Model

The Internet as a Unique Medium for Dating

This section discusses the characteristics of the Internet as a delivery system in terms of immediacy of feedback, multiple cues, language variety, and personal focus. The discussion reveals that the characteristics of the Internet facilitate easier manipulation of information and increase the incidence of disinformation.

Medium as the Message

When a new technology emerges, its form deserves careful study, for "the medium is the message" (McLuhan, 1964). Let us borrow McLuhan's example of the light bulb invention for illustration. A light bulb does not possess or deliver content in a way a newspaper article or television program does. It has no information content, but it creates space, or environment. The created space offers new possibilities; for instance, it enables people to work in what otherwise would be complete darkness. In this sense, a light bulb, by its mere presence, opens up new possibilities and new influences. Similarly, the invention of the Internet does not merely give a new tool for information collection and circulation; it creates a virtual world that awakens and develops new dimensions of human interactions, revises the sense of authenticity, and excites new imaginations. Research finds that different communication media, for the social purpose of uncertainty reduction, vary in their abilities to convey knowledge and information (Daft & Lengel, 1984, 1987; Newberry, 2001; Trevino, Lengel, & Daft,, 1987). A medium, such as face-to-face communication or electronic mail, may be labeled "rich" or "lean" depending on the following four abilities: (1) immediacy of feedback; (2) capacity to transmit multiple cues; (3) language variety; and (4) personal focus (Daft & Lengel, 1984). We now consider these four capabilities of the Internet and their implications for cyberdating.

Immediacy of Feedback

"Immediacy of feedback" refers to a medium's speed in transmitting feedback. A "richer" medium provides more immediate feedback, making it easier for communicators to adjust their responses to received messages (such as signaling understanding, confusion, or disagreement). Some electronic communication channels, such as the E-mail, Instant Messenger (IM), Multiple User Dialogue (MUD), allow cyberdaters to receive much faster replies from their partners than supported by traditional (postal) mail. Compared with face-to-face communication, however, these electronic media may offer a more limited capability for feedback immediacy, as many forms of electronic communication are not as mutually immediate as face-to-face communication. Today, the bulk of electronic communication still happens largely in two separate steps: message sending and *then* message receiving (Herring, 1999). Synchronization in face-to-face communication may appear more pronounced, even compared with the so-called synchronous electronic communication of video chatting and video conference. The face-to-face conversationalist does not have to finish, for instance, "I lo(ve)" before the partner can chime in.

Communication studies suggest that interpersonal relationship development depends heavily on instant and simultaneous interactions. Even more important is the individual's ability to freely and simultaneously switch between the roles of Sender and Receiver. Thus, face-to-face interaction seems to provide more feedback immediacy and should therefore better facilitate relationship growth than does electronic communication. The Internet's inferior feedback immediacy may also be expected to cause a certain degree of frustration, with consequent negative impact on the communicators' attitude toward information quality and trust acquisition in cyberdating.

Multiple Cues

"Multiple cues" refer to the medium's ability to convey varied types of information that appeal to different senses of the communicators. Rich media allow a fuller range of verbal, paralinguistic, intonation, proxemics, kinetic, olfactory, and tactile cues to convey the subtleties and implications of a message in addition to the message's literal content (Lim & Benbasat, 2000). Some researchers call the "surplus" cues of rich media "social cues" as they enhance social interaction (Daft, Lengel, & Trevino, 1987; Farmer & Hyatt, 1994). The Internet may deprive cyberdaters of numerous "social cues" that are available in face-to-face communication (e.g., the tactile and the olfactory). Both research and intuitive experience suggest that such factors as gender, age, personal appearance, and physical build carry great significance in the development of romantic relationships, especially in the early stages. Absent of the desired visual appeals, a relationship my not start or may end abruptly. As the relationship grows, visual, auditory, olfactory, and tactile conveyance of motions and emotions remain strongly desired. Communicators depend on a large spectrum of signs of various types to verify the truth of information, a critical element of trust acquisition and maintenance. Suspicion is likely, for instance, when the communicator detects avoidance of eye contact and other signs of discomfort in conversation. In addition, communicators rely on the consistency of behavioral patterns for detection of disinformation or lies. Behavioral consistency is generally associated with honesty and behavioral inconsistency with deception regardless of the specific behaviors that are enacted (Henningsen, Cruz, & Morr, 2000). In its present state and compared with face-to-face communication, the Internet has limited capabilities in providing the full range of social cues that are necessary to facilitate information authentication and trust acquisition.

Language Variety

"Language variety" relates to the range and scope of meaning that language symbols may convey (Farmer & Hyatt, 1994). For instance, numbers generally convey more precise meaning than the lexical language (Daft et al., 1987), while graphic symbols carry a greater range of interpretations (Daft & Lengel, 1984). Some information may be easier to convey in one format than in another. Facial features tend to be more accurately portrayed in a photograph, whereas an action is better captured in a video. The Internet may enhance the transmission of quantifiable or "codify-able" information. An online communication about a math problem and its calculation may be less daunting compared with an oral explanation of the same that relies solely on face-to-face interaction. Romantic relationships, however, tend to focus on non-quantifiable, difficult-to-code expressions of emotions. Mere textual transcriptions, on which much electronic media rely, contribute to the troubling incidence of unintended implication and interpretation. To help their understanding of an online textual message, cyberdaters often resort to contrived techniques to reduce qualitative emotions to quantifiable codes required by the electronic media. Keyboard characters are used to simulate facial expressions and paralinguistic features of conversation, referred to as "emoticons" or emotional icons (e.g., :-) or ☺ to imply a smiling face). The person that wishes to have his/her message interpreted as friendly teasing, for example, may have to interpose the extra and extraneous word or phrase of "grin" or "just kidding" (Parks & Floyd, 1996). The consequence of low language variety of the Internet will receive more discussion later in the chapter.

Personal Focus

"Personal focus" refers to a medium's ability to facilitate the communicator's expression of personal feelings and emotions. For greater personal focus, messages need to be tailored to the frame of reference, needs, and current situation of the receiver (Daft et al., 1987). Greater "personal focus" helps to project the communicator socially and affectively into a community of inquiry (Rourke, Anderson, Garrison, & Archer, 1999; Russo, 2000). A rich medium, such as face-to-face interaction, may offer greater personal focus by enabling the communicator to see the partner as a real, physical human being. In cyberdating, however, the participant is one step removed from the partner and addresses but the immediate presence of an inanimate computer, compromising the personal focus of electronic messages.

The features discussed above of the delivery system may represent a double-edged sword to cyberdaters. On the one hand, electronic communication better serves cyberdaters' need for a greater quantity of information and enables them to multi-communicate with several people at the same time. The anonymity and physical absence of the communicators offer exciting space of imagination and creativity. However, the media "leanness" of the Internet deprives cyberdaters of important social cues that are necessary for information authentication and trust acquisition. In other words, the delivery system affects the information environment, the negotiation of which will be the topic for the forthcoming two sections.

Misinformation and Disinformation: What does it mean?

Misinformation in cyberdating may be approached from three angles: intention, reception, and situational desirability. The term misinformation is used here to mean the discrepancy between what a word or a sign (or a series of signs) signifies and the reality it references. Misinformation, though generally perceived as negative, may be more prevalent than we are willing to acknowledge. A candid reflection on misinformation, adhering strictly to the above definition, may point to a near omnipresence of misinformation in everyday life. The prevalence of misinformation may become understandable when we reflect on the challenges of *not* misinforming. Any given piece of information simply cannot contain the multifaceted and variegated totality of reality. "A white sheet of paper" fails to inform about the shades of whiteness, the length, width, and thickness of the paper, its quality, desirability, and availability. When asked "How are you?" people more than likely choose to offer the simple response of "doing fine" and will not delve into every annoying detail in their life. "I love you" means, in frank analysis, "I love you at this time and place when I am feeling this emotion." The simple expression of "I love you" may have missed the temporal and spatial frame of reference, as hardly any love could inoculate itself from the corrosive detritus of time, life, and society. Misinformation is so deep-seated in everyday life that much of it is unconsciously treated as innocuous. However, misinformation in cyberdating could be much less innocuous.

Misinformation and Intention

If interpreted according to the definition discussed earlier, misinformation could hardly be avoided in any normal conversation.

Popular interpretation of misinformation, however, often associates it with intention. For distinction, some scholars choose to label unintended inaccurate information as "*mis*information" (See, e.g., Chapter 23). A piece of information will only be interpreted and perceived as *dis*information when a strategic purpose is assigned to the distortion of this information. The mundane and oft-used term of "lying" refers to what our more scholarly term of "disinformation" purports to denote here. According to Reboul (2001), "The speaker of a lie has the intention to produce a specific effect: that his [or her] hearer should believe something which the speaker takes, rightly or wrongly, to be false" (p. 20). Grice (1989) identifies two major ways to achieve the intended effect of a lie: (1) You can say something you believe to be false and get your hearer to perceive it as true. (2) You can say something you believe to be true and get your hearer to take it as false. Much disinformation in cyberdating tends to revolve around personal identity and social status, including one's age, looks, height, profession, and income, all of which may seem important for meaningful relationship development.

Disinformation and Reception

From the Receiver's perspective, communicated information will tend to be treated as valid unless it is *discovered* and *recognized* as disinformation by the Receiver. For instance, a man may remain a perfect date, humorous, well-off, and kind, until the woman finds out that he is already married with three kids. The revelation brings the woman to realize what she had thought to be true information is in fact disinformation. Such a discovery requires that the Receiver relies on the following data: (1) the conventional meaning of the words used and the references signified by these words; (2) rules that both the Sender and Receiver observe; (3) the context of the utterance; (4) items of background knowledge; and (5) the fact claimed or implied by the previous four factors is available for verification by both Sender and Receiver (Grice, 1989, p. 30). These five types of necessary data for detection of disinformation, or rather the difficulty involved in their acquisition, make disinformation detection a rather arduous task in cyberdating. Data types four and five may be especially hard to obtain for cyberdaters.

Misinformation and Situational Desirability

Different cyberdaters may manifest different reactions and attitudes toward the same piece of (mis)information or (dis)information, depending on their individual expectations for cyberdating. For some, the desirable outcome may be to find the true love with whom to "live happily ever after." For this group, authentic information is crucial. Disappointment is immediate upon the detection of falsehood and disinformation, especially when it involves such important factors as age, physical build, gender, and economic status. Hardey (2004) corroborates that informational authenticity is valued in many cyberdating sites where successful communication depends on the development of trust between strangers.

Discovery of the "true love" may not be the end result desired by other cyberdaters, however. These cyberdaters dive into the virtual space perhaps to find the new, the mysterious, the alternative, and the excitement that are not readily available in the face-to-face world. Textual exchange and the virtual world created thereby may prove sufficient for these cyberdaters' expectations and their platonic wish for "emotional communication, with others and with the self" (Giddens, 1992, p. 130). Such cyberdaters may be content, for instance, when the exchanged messages resonate with their deep feelings and emotional vibrations; whether the messages originate from a puppy, a young girl, or an old man may be of little concern. Investigation and verification of information authenticity may be of much less importance to this group as opposed to the previous group of "seekers of the true love." Deviations from mundane reality and hackneyed truths (such as creative identities and imagined locations of an ethereal nature) may even be what these cyberdaters strive to achieve.

When cyberspace is intended as an initial step that will hopefully extend into face-to-face interactions, cyberdaters have to decide whether they can trust the encountered information, and consequently, how they can ensure that the information is truthful.

Trust: Where does it come from?

Do cyberdaters commence their romantic ventures with an assumed trust before being proved wrong? Or do they start with a suspicious distrust until actual trust is obtained? According to Grice (1989), trust operates on two levels: (1) trust of cooperative intention between the two parties; and (2) acceptance of the exchanged message content as true. The very presence of the cyberdater in virtual space may communicate the trust of cooperative intention, a purposeful intention to participate in online dating. Lack of pre-established and pre-online interaction with the partner, however, complicates Grice's second level of trust in cyberdating.

Grice's Cooperative Principle

Grice (1975) proposes that there is an accepted way of speaking, endorsed by all participants as standard behavior. Meaningful execution of communication presupposes a communal agreement on certain behavioral principles. He calls this agreement the Cooperative Principle (CP), which is further divided into maxims of quality, quantity, relation, and manner.

According to the cooperative principle, when people send or receive an utterance in purposeful communication, they assume that the utterance is true (quality), provides adequate information (quantity), is relevant (relation), and clear (manner). Practice in real life communication testifies both to the evident and widespread belief in the social norm of cooperative principle. It also testifies to the frequent breach of this norm. As a result, two distinct responses are equally possible towards infraction of the cooperative principle. One, it is perceived as violation of the cooperative principle and commission of falsehood, leading to loss of trust. Two, it is perceived to insinuate an alternative or unusual connotation, or in Grice's term, conversational implicature. For illustration, let's use the following simple conversational transaction:

> Tom: How's your new date?
>
> Tracy: A big success.
>
> Tom: Oh, Ok (with either a wry or sympathetic smile).

For Tom, Tracy's response is evidently her attempt to address his question, therefore, relevant. Tracy answers his question in no ambiguous terms and thus observes the maxim of manner. In addition, Tracy seems to be honoring the maxim of quantity, not saying more or less than required by Tom's question. However, in terms of the maxim of quality, Tom may derive two different interpretations of Tracy's response. One, Tracy is telling the truth as her date is actually a success and a great satisfaction to her. Two, Tracy's new date turns out to be a total disaster; Tracy's message either attempts to dissemble the truth or is intended as irony and she wants no more discussion of her dating nightmare. Both of Tom's interpretations could prove plausible in real communication. In a face-to-face setting, Tom's interpretation of Tracy's response as truth or falsehood, as direct response or irony, or as observance or breach of the maxim of quality, may depend largely on the way that Tracy utters the response. Extra-textual cues are of indispensable service here, corroborating the popular saying that the real message may lie in the unsaid. "Hearers assume that an utterance addressed to them is intended to be meaningful. Therefore, if the utterance doesn't have an appropriate conventional meaning, they will look for a more useful interpretation" (Davies, 2000, p. 18). It is frequently the availability of extra-textual cues that help generate alternative interpretations of ambiguous messages and in turn aid the Receiver to grasp the real and implied intention (or the conversational implicature) of the Sender.

Cooperative Principle and Trust in Cyberdating

In cyber romance, as in any other romantic interaction, the first level of trust (i.e., cooperative intention), generally speaking, is distinctively there. Many online services such as matchmaker.com communicate an express purpose for their services. The very presence of the cyberdater in the virtual space of such online services consequently communicates a purposeful intention to participate and cooperate in electronic communication. However, the second level of trust—trust in truthfulness—is another issue. Clear manifestation of the first level of trust, compounded with the elusive nature of the second level of trust, makes cyberdating a rather intriguing and yet often dilemmatic experience. The cyberdater may be confounded by the disparity between the unequivocal trust of cooperative intention and the suspicion over textual messages. The "leanness" of the Internet as a medium simply exacerbates the problem.

Trust of content, unlike trust of cooperative intention, cannot be assumed but has to be actually acquired. The Internet's limited capabilities in providing multiple cues spur cyberdaters to make adaptations of traditional means of acquiring the second level of trust. Many, especially those engaged in textual chatting, choose to focus less on the actual looks and other physical aspects of the partner, and more on internal qualities of the partner (e.g., educational level and social finesse as inferred from textual messages). The more lax observance of social norms in cyberspace may actually accelerate revelation of one's true state in nonphysical aspects.

Studies (e.g., Merkle & Richardson, 2000) have shown, however, that physical attractiveness and attitudinal similarity are important factors for developing an inchoate encounter into a sustained relationship. Physical attractiveness in initial romantic encounters seems to clearly outweigh other factors. A minute detail in physical appearance may lead to either a hasty intensification of interest or an abrupt termination of interest in a stranger.

Lack of visual and certainly tactile and olfactory elements in the majority of online dating channels favors a propensity toward the nonphysical and spiritual qualities of a partner. Physical attractiveness may give way to personality, as constructed and presented by the partner's textually coded thoughts. If governed by the cooperative principle, the nimbly synchronized maneuvers between reading, writing and message volleying may efficiently guide the cyberdater to a rather accurate gauge of the partner's personality, values, and attitudes. Shared "vocabularies of bodily idioms", viewed by Goffman (1959) as central to the "presentation of self" in public, are exchanged in the cyberspace for the development of cyber-relationships, through which a (virtual) sense of trust is constructed.

Grice's maxim of manner or clarity is often compromised in face-to-face interactions because of social etiquette. Although clarity and efficiency in communication may call for blunt terms, people typically employ pleasant terms, particularly in expression of negative feelings, at the early stage of relationship development. Under the pressure of social decency, self-disclosure may come late and progress at a pace endorsed by relationship development. A communicator could be easily offended, for instance, if a stranger abruptly initiates the question, "Hello, how old are you?" or if the stranger discloses too many personal secrets too early. One step removed and more liberated from the restraint of social etiquette, cyberdaters in contrast seem to self-disclose much more information much more quickly. Immediately upon arrival into the chatroom, the cyberdater may fire a barrage of questions for efficient collection of important information about his/her potential partner (e.g., the use of the abbreviation "asl?" for efficient collection of information regarding the partner's age, sex, and location).

Merkle and Richardson (2000) speculated that this change of norms and expectations is due to the anonymity provided by the Internet, greatly reducing participants' social qualms. Reduced visual and auditory cues may also play a role in facilitating self-disclosure. However, the laxity of social etiquette in cyberspace could prove both a boon and a bane. On the one hand, communication could be liberated from social restraints so as to focus more on clarity, efficiency, and hard truths. On the other hand, the same features of the Internet may slacken participants' sense of caution, facilitates information manipulation and dissemblance, and contribute to the occurrence of fraud and disinformation. Other factors may also play into the operation of trust in cyberdating: less spatial confinement, greater difficulty in physically tracking the participant, elusive behavioral accountability, and lack of relationship sustainability due to easy and flippant initiations and terminations of interactions. More studies are needed to investigate the negative and positive effects that the distinctive medium features of the Internet could exert on the operation of trust in cyberdating. We now consider one case of cyberdating, demonstrating how trust in the cyberspace is assumed, acted upon, and then lost when disinformation is detected.

An Example of Disinformation in Cyberdating

A clear breach of the cooperative principle, when detected, will normally lead to an immediate termination of communication. How do communicators detect such a breach when it occurs online? The case we now present illustrates how online trust can be assumed, acted upon, abused, and then lost. It also demonstrates how the detection of online fraud may require extension of the online interaction into the face-to-face world, thereby bringing the cyberdater into an environment where the dangers are no longer purely virtual and emotional but concretely tangible.

A Narrated Case of Cyberdating and Fraud

This case is cited from www.wenxuecity.com ("Man with over 200 online wives," 2003), a major Chinese website featuring news, entertainment, and forums. The story is narrated in first person allegedly by a young lady. She accused a man of online cheating by exploiting the trust of more than 200 of his "virtual wives":

> I came across D-Cat, the man, in a private chat room. After initial greeting and self-introduction, D-Cat offered to tell me that he'd just come back from Germany after four long years. I had learned from a female cyber friend that D-Cat had offered to give her a cellular phone for "further contacts." I was not involved with D-Cat in any romantic sense, and did not plan that way. I was only curious as to why he had made that cellular phone offer to that female friend of mine. He explained that he once owned "emotional debts" to the female gender [the original wording is *nǚ xing*—female gender. Contextually, it should be interpreted as that particular cyber friend of the narrator, or the "sweetheart," in D-Cat's term], and wanted to make it up materially. In addition, he was suffering from cancer, so money had lost much of its meaning for him.
>
> The turning point was at our first face-to-face meeting. D-Cat did not make a very positive impression on me with his disproportioned body shape and a big paunch. I also noticed that he has thick hair and healthy complexion that could hardly be associated with chemo patients. At this meeting, he revealed more of himself. His father died when he was little. His stepfather, who was in the steel business, had paid hundreds of thousands of dollars for treatment of the young man's lung cancer. Seeing that I looked sympathetic, he asked me to lend him some money so that he could make calls to his "sweetheart." This rhetoric of money borrowing did not strike me as plausible, plus the fact that he neither looked nor sounded like suffering from a fatal disease. All the clues so far turned my suspicion on. Soon after our face-to-face meeting, I managed to get his password and got into his QQ mailbox. To my surprise, he had over 200 female cyber friends, all of whom he referred to as his "dear wives." He abused their trust in him, and cheated them out of their money [when they placed trust in him]…

In this narrated interaction, D-Cat was guilty of patent disinformation, with strategy and premeditation. He lured the other gender with material attractions (e.g., the promise to buy the girl friend a cellular phone); he lied about his background, and particularly his health condition for the strategic purpose of cultivating others' sympathy; he cheated hundreds of people out of their money. The reader may question the validity of this particular piece of narrative, which could be a perfect fabrication. However, as our focus in this work is analysis of trust in the cyberspace, we might as well overlook the authenticity of the story itself, and focus instead on the "hypothetical realism" of the story to facilitate our analysis. What follows is an analysis of how disinformation is detected and trust lost in the narrated story.

Analysis of Disinformation Detection in the Case

It is not easy to acquire complete data to determine how well Grice's cooperative principle is observed in a communicational transaction. The difficulty may be exacerbated for cyberdaters as they have to rely on limited channels of lean information in the cyberspace. Authentication of information or detection of disinformation becomes treacherous tasks. Relaxed social norms and lack of behavioral accountability may also contribute to the relative ease of the production of disinformation and deception in cyberspace.

Before her face-to-face meeting with D-Cat, the narrator in the previous story found herself passively interpreting the messages the way they were strategically and deceptively designed. On the surface, every verbal message exchanged fit in with the Cooperative Principle; she did not detect any flouting or breach of the maxims. The only signal of extra-textual meaning (i.e., meaning in addition to that generated by the textual message) arose with the topic of the cellular phone. Her real-life experience led her to believe that material offering in a cyber relationship might signal hidden motives—"young men nowadays are very realistic; they won't spend time and money for you if they could not get sexual gratification and/or more money in return," as she later related. Unfortunately, the discrepancy between what her cyber partner verbally communicated and what her life experience taught her serves as the only indicator of possible breaching of the maxim of quality. Her suspicion remains on the level of conjecture without solid verification.

Her sense of being misinformed began to materialize only after her face-to-face encounter with her partner, D-Cat. The added visual cues in the face-to-face encounter enabled her to verify what she read against what she saw, revealing disinformation in her partner's electronic communication regarding his cancer. This revelation alerted her to exercise caution. D-Cat's further communication in the face-to-face encounter corroborated the narrator's suspicion. He began to disclose to her about his father and stepfather, a self-disclosure that went beyond what social norms would endorse at the early stage of relationship development. In this sense, D-Cat violated the maxim of quantity, which requires the Speaker to tell no more or no less than warranted by conventional needs of communication. Although Internet users may pardon and accept in cyberspace a higher level of self-disclosure that may appear inappropriate in face-to-face encounters, violation of the maxim of quantity in real-life world certainly raises the red-flag of suspicion. D-Cat's excessive disclosure in the face-to-face interaction inclined the narrator toward a suspicion of ulterior motives. D-Cat's expressed interest to borrow money clinched the narrator's suspicion. Chinese culture frowns upon an effort to borrow money from strangers (which D-Cat and the narrator were, except for their immature electronic and impersonal exchanges in cyberspace). All of such detection, however, came as a result of face-to-face encounter, which provides many communicational cues unavailable in the cyberspace. Sole reliance on cyber-communication might not have led the narrator to the same conclusion.

It is not a coincidence in the narrated case that verbal messages began to generate new meanings during the face-to-face interaction. Face-to-face encounters are the desired and indispensable extension of cyberdating for many participants, as the former provides cyberdaters numerous benefits unavailable in the latter. In a comparative study between online and offline romantic relationships, McDowell (2001) listed sixteen types of turning points in relationship development. The following are the three types where online relationship development becomes statistically significantly different from offline relationships: (1) initial face-to-face meeting, (2) significant shifts in media, and (3) exclusivity. McDowell finds that the initial face-to-face meeting with one's significant other (either a positive or negative experience) is considered to be the most important turning point in relationship development, leading to crucial changes in commitment levels. The initial face-to-face meeting was mentioned almost exclusively by the online group, ranked as the third most important turning point by this group. For the offline group, however, initial face-to-face encounter appeared as the least important turning point in relationship development (16th). For other critical turning points, online participants cited "significant shifts in media or in exchange of personal information" 12 times as often as do the offline group. Significant shifts in media refers to the expansion of communication to new types of media (e.g., from phone calls to email exchanges, from email to photo sharing). Significant shifts in exchange of personal information refer to changes in revelation of personal information (e.g., from disclosure of first names to that of last names, from disclosure of real age to exchanging of phone numbers or email addresses). The different reports by the online and offline groups regarding critical turning points in relationship development may be because shift in media in online relationships represent significant increases in the number of channels (e.g., vocal, visual). Media changes for cyberdaters often mean a new and otherwise unavailable ability to gain additional information about the partner (McDowell, 2001).

Another research by Parks and Roberts (1998) reports that, of the respondents that initiated relationships on a MOO (Multi-User Dimensions, Object Oriented, a real-time, text-based virtual environment), 80% had also contacted their partner via email; 66.8% had spoken on the telephone; 54.5% had communicated by writing (cards or letters); 40.5% had exchanged photos by mail; and 37.7 % reported that they had gone on to meet their partner in person. Partners in romantic relationships were the most likely to eventually meet face-to-face (57.9% according to McDowell, 2001). This is confirmed by reports of mail, telephone, photo exchange as additional means that supplement computer-mediated communication (Ogan, 1993; Parks & Floyd, 1996; Reid, 1991).

Discussion and analysis in this section indicate that computer-mediated communication, due to various limitations in communicational capability, may not be a sufficient channel of communication for meaningful development and fruition of romantic relationships. Supplementary channels of communication (e.g., phones, traditional mail, face-to-face interactions) appear to be desirable and perhaps even indispensable. The following section points cyberdaters to additional suggestions and reminders for their online romantic ventures.

Implications for Cyberdaters in Information Exchange

So far we have focused on two of the major components of the Informing Science—the delivery system and information environment. More specifically, we considered how characteristics unique to the Internet could impact issues of disinformation and trust in cyberdating.

Based upon this analysis, we now offer some practical suggestions and reminders for cyberdaters.

Distinction between Two Levels of Trust

As with offline interaction, cyberdaters need to be aware of the two distinct, yet overlapping, levels of trust—that of the cooperative intention and that of message truthfulness. As the former serves as the pre-requisite for the initiation of meaningful interaction, its existence may be assumed in many cyber venues designed expressly for dating services. The latter, however, must be worked out and actually achieved via information authentication and/or disinformation detection. As the Internet is a rather lean medium for human interaction, frequently depriving communicators of valuable and essential communicational cues, cyberdaters need to exercise extra caution regarding the possibility of disinformation. Information authentication and verification must occur before trust is given. Cyberdaters may find it necessary to employ supplementary channels to remedy the "leanness" of electronic interactions. Yet at the same time cyberdaters need to be aware of the potential risks and new complications that may arise when electronic interaction is extended into other modalities of communication (especially face-to-face communication).

Separation between Sender Role and Receiver Role

Keep in mind that the Sender and the Receiver are not identical roles. Each is associated with distinct assumptions and strategies. This distinction is of special significance in cyberdating. The Receiver needs to trust the sent message so as to create the requisite condition for the initiation of interaction. The Sender in cyberspace, however, is obliged only by the self-policed social etiquette of truthfulness. As the Sender may choose to manipulate and distort information for negative strategic purposes, the Receiver has to go the extra mile to figure out the authenticity and truthfulness of the Sender's information. Success in the real world's face-to-face communication requires competence in both roles and adept switching between the roles that is appropriate to the situation or the participant's wishes. In cyberspace where communication frequently occurs in delayed steps, people need to distinguish the two roles so as to see more clearly what is possible with the role of the Sender and what to do in the role of Receiver.

The Double-Edged Sword of Online Anonymity

Cyberspace enables anonymity. Anonymity, however, can be both boon and bane, creating exciting possibilities and engendering troubling risks. Cyberdaters are often enthusiastic about the lack of constraints and ability to give their imaginations free reign that online anonymity brings to them. In cyber space, they feel emancipated from the sticky web of social norms and moral restraints. They are ready for some "free play" with new identities. They are eager to dive into the deepest truths of human existence. Cyberspace offers a new venue for truth, nothing but the blunt truth. However, the new freedoms in cyberspace can also be abused for strategic manipulations that are not endorsed, and may even be condemned, in the real world. Online anonymity, for instance, makes it hard, if not impossible, to physically track communication participants and to assure behavioral accountability. Lack of spatial confinement makes the cyberspace a free market. Anyone can come, leave, or express themselves in a manner that does not respect even the slightest principle of social decency. Cyberdaters must not forget that the evil edge of the sword of cyberspace may be used just as often as the noble edge.

Risk of Extension of Online Interaction

Because of the limitations of cyberdating (e.g., lack of tactile and olfactory senses), many participants strive to extend their virtual interaction into physical contact. However, the cyberdater must understand that premises of online interaction greatly differ from those of face-to-face interaction. The former may proceed and continue in the haze of fabricated identities and imagined existences. In other words, interactions can continue with assumed trust and even in the absence of trust as well. Face-to-face communication, however, needs to proceed on the solid foundation of verified identities and truthful information. Success of face-to-face communication depends on established trust. Communication in the real world, if based on the gossamer premises of online communication, may lead to disasters of rape and murder. Due to the limitations of cyberspace, it is advisable that cyberdaters admonish themselves to realistically frame their expectations for cyberdating. The process of extending cyberdating into real dating must be handled with caution and with modification of foundational premises. Cyber participants may choose to be content with the experience of just "talking" to their cyber soul-mates for platonic understanding, care, affection, and comfort. It is advisable to refrain from physical contact before online interactions have produced the mature conditions required for successful communication in the real world.

Conclusion

A statement by a netizen self-identified as Dan (2006) may serve as an apt endnote to conclude this work: "Online dating sites and chat rooms make it easy for predators to find victims, phishing scams trick people into giving away their life savings and children can come across inappropriate material far too easily. Then again, life before the Internet was not devoid of problems. Predators still found victims, chain letters and other forms of scams still managed to swindle people out of their money, and children could still be exposed to filth. Instead of creating these problems, it would seem the Internet is guilty of making it easier for them to happen. It's also possible that the frequency of these problems has not increased, but that the wealth of information we now enjoy makes it appear that the problems are more frequent than before."

This paper argues that the characteristics unique to the Internet medium clearly differentiate cyberdating from dating in the real world. The creation, reception, and interpretation of disinformation functions differently in the virtual space. Trust emerges and operates differently in the virtual space. Premises that enable online interaction may prove insufficient to produce meaningful face-to-face communication. Cyberdaters must understand the different nature of virtual interaction in order to exploit the Internet's exciting possibilities successfully and wisely avoid undesirable and tragic consequences when online interaction is carelessly extended into real world face-to-face encounters.

The readers may have noticed that this work largely confines itself to the discussion of the most popular and the more traditional modality for cyberdating—textual chatting. New developments in Internet technology are adding additional communicational capabilities to the Internet, such as visuality and even a simulated sense of tactility (Noe, 2008). Studies of these new capabilities of the Internet are necessary to further the investigation of human interaction in the virtual space.

Computer technology, and particularly the Internet, had led to a revolution in mediated human interaction--extending face-to-face communications and ushering in an era of new possibilities and new problems. Traditional issues in face-to-face human interaction such as disinformation and trust, once positioned in the mediated space, seem to acquire different facets and pose new issues. Studies of mediated human interaction provide a fertile land for research by scholars of human communication. We hope this chapter will serve as an invitation to explore this fertile land within the field of Informing Science.

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Chapter 19

Web ACE – A Study in Reciprocal Informing

Iwona Miliszewska and Grace Tan

Introduction

The Computer Science degree at Victoria University is a three-year full time program, and the majority of students enter the course as school-leavers. A significant part of the degree is a final year subject – the Project. The Project, regarded as a 'dress rehearsal' for computing students about to graduate and face the needs of the commercial and industrial world, places special emphasis on consolidation of problem solving skills, and the enhancement of associated communication skills. This emphasis is particularly timely as a national report on Employer Satisfaction with Graduate Skills (AC Nielsen Research Services, 2000) found that Computer Science graduates were lacking in both areas. Relatively low ratings were given for both written and oral business communication skills, initiative, leadership qualities, personal presentation, and problem solving skills. The Project provides students with an opportunity to develop and improve these essential skills before they enter the workforce and, as such, it is likely to influence their future employability.

Project students, under the supervision of a staff member, tackle a software development problem for a company or organisation. Typical projects include design and development of database applications, web based applications, or software modules for computer packages; integration and enhancement of existing software modules; and system analysis and simulation studies of production and inventory systems. Students are divided into groups of three to four members; each group is allocated a project, a sponsor – the client – and an academic supervisor. Each group works on their project, while liaising with the client and consulting with the supervisor, submits reports, and gives presentations. Their work is further helped and scrutinised by the English lecturers who, while not familiar with the computing side of the projects, are language and communication experts. They play a vital role in helping the often reluctant computing students realise the importance of good communication skills: the effect of an articulate interview, the impact of well structured and clear reports, and the power of well prepared presentations.

Typically, during the course of the Project subject, students would only learn language and communication skills from their English lecturers and, in turn, the lecturers would only teach those skills, i.e. the roles of the participating parties would be well defined and one-sided. Referring to the Informing Science paradigm (Cohen, 1999), students, as learners/clients, would be on the receiving side of information, and lecturers would play the role of teachers/providers. This division of roles and a single platform of interaction – language and communication – left little, if any, room for reciprocal learning between students and lecturers. Could this reciprocity of roles be realised in the Project environment?

This chapter reports on a unique Project experience that provided an answer to the above challenge. In the case now described, students developed a Web based content management system (Web ACE) for their English lecturers; the name for the new system was derived from the English subject code – ACE3144. The chapter identifies the unique opportunities presented by this Project experience, and refers them to related research findings. The chapter describes the development process from its conception to final deployment and explicates it in terms of the informing science framework (Cohen, 1999); the introduction of a second platform of interaction – information technology – that enabled reciprocal teaching and learning; and, the benefits that all participants gained from the experience.

The Project

The aim of the Project is to provide students with an opportunity to work on a real-life software development task; to appreciate the needs of the business client for whom they are expected to build the software system; to apply software engineering and database design methodologies to the design and implementation of a complete system; to confront issues developers face on a daily basis, such as liaison with clients, working in a team, and documenting the system; to gain experience in translating their knowledge into practice; and, to obtain feedback concerning their progress from intensive reviews of their work.

Underlying Conceptual Frameworks

Firstly, the Project promotes Problem Based Learning (PBL). Many variations of PBL have been documented, but all of them include situations where an initial problem serves as a catalyst for subsequent learning (Fogarty, 1997; Kingsland, 1996). The learning that occurs in working with the problem enables students to develop new knowledge, as well as further consolidate their existing skills and knowledge (Schiller, Ostwald & Chen, 1994). Students have a greater responsibility for their own learning and receive less guidance from the teacher, factors distinguishing PBL from subject-based learning (Dolmans, 1992). The role of the teacher is different too: it is one of consultant rather than instructor. PBL usually includes a collaborative component; students often work in groups where collective decisions are made about task distribution, and where group members investigate different aspects of the problem that together contribute to the total solution. PBL is often project based, with the project work varying in complexity and scope from a project exercise, through a project component and project orientation (Morgan, 1984). 'Project orientation' represents the most advanced end of the PBL spectrum, as it describes a curriculum philosophy in which the projects that students complete form the entire basis of their university education; project work constitutes the central and dominant component of the curriculum and conventional didactic teaching is only provided to supplement the requirements of the project topics.

Secondly, in addition to PBL in a collaborative environment, the Project targets the pursuit of worthwhile tasks, that is, real projects commissioned by real clients. The emphasis on 'authentic' tasks, PBL, and collaboration exemplify the three components of another framework for learning – Engagement Theory. *The major premise of engagement theory is that students must be engaged in their course work in order for effective learning to occur. The theory posits three primary means to accomplish engagement: (1) an emphasis on collaborative efforts, (2) project-based assignments, and (3) non-academic focus. It is suggested that these three methods result in learning that is creative, meaningful, and authentic* (Kearsley & Schneiderman, 1999). Engagement theory is based on the idea of creating successful collaborative teams that work on tasks that are meaningful to someone outside the classroom. Its core principles are summarized as "Relate", which emphasizes characteristics such as communication and social skills that are involved in team effort; "Create", which regards learning as a creative, purposeful activity; and “Donate”, which encourages learners to position their learning in terms of wider community involvement.

Thirdly, the Project is the final and all-encompassing subject in the degree program. It is a culminating experience in which students synthesize and consolidate knowledge acquired throughout their studies. Fairchild & Taylor (2000) define such experience as a Capstone . In addition to integration, experiential learning, and real-world problem solving, capstone emphasizes teamwork, decision-making, critical thinking, and interpersonal communication. These are non-technical skills considered essential in many types of work, and computing work is no exception; graduates are expected to demonstrate technical skills, as well as project management skills and awareness of business practices (Fairchild & Taylor, 2000; Magney, 1996; Novitzki, 1998; AC Nielsen Research Services, 2000).

Lastly, and ideally, the Project should also be an instance of reciprocal learning. Project students should learn from the Project experience and, at the same time, communicate their computing knowledge to others, particularly, their fellow project group members and project sponsors. Research promotes reciprocal roles of teachers and learners, and stresses their interdependence (McLoughlin & Oliver, 1999) as well as advocating a shared responsibility for creating and exploring knowledge (Scardamalia & Bereiter, 1991; 1994).

Application of all the above frameworks helps ensure the educational quality of the Project, as it supports the universal seven principles for good practice in undergraduate education: encourages contact between students and lecturers; develops reciprocity and cooperation among students; encourages active learning; gives prompt feedback; emphasises time on task; communicates high expectations; and, respects diverse talents and ways of learning (Chickering & Gamson, 1987; Chickering & Gamson, 1991; Chickering & Ehrmann, 1996).

Project Model

Guided by the frameworks presented above, the Project was included as a mandatory subject in the Computer Science degree in order to enable students to consolidate the knowledge and skills gained throughout the degree. As a consequence, an elaborate system of supervision exists to support Project students. Students form groups of three to four members and nominate a group leader; each group is allocated an industry project (task) and an academic supervisor. The projects are sourced, by the Project coordinator, from local business and industry, and typically are applications of interest to the clients (project sponsors). Although the problems are situated in the 'real-world', the pressure on the students for successful completion is minimized. Thus, students are able to concentrate on the problem in hand. They can proceed at a pace that enables them to gain maximum benefit from the experience, and complete work that is of high standard.

Once the projects have been allocated, students contact their supervisor to arrange the initial meeting with the client/sponsor. Meetings with supervisors take place every week. Each group keeps a logbook used to scribble ideas, designs, and bits of codes, and to record the number of hours spent on the project. During the course of the Project, each group submits a number of documents including the logbook and project reports; gives oral presentations to fellow students and project supervisors at various stages throughout the year; and, finally, demonstrates its software system. Project groups present all the facets of their systems and reply to any questions regarding functionality and implementation. Grades are awarded on reports, oral presentations, and software demonstration.

English Language and Communication

Students undertaking the Project enrol in a co-requisite subject in English Language and Communication. This subject builds on language and research skills acquired earlier and it has two goals: to provide students with advanced written and oral communication skills necessary for successful completion of their academic studies, particularly the Project; and, to provide preliminary preparation for future employment.

With respect to academic studies, the subject emphasises the development of skills such as listening and note taking, reading and summarising, locating and assessing information sources, writing reports, and making oral presentations. Students apply these skills to the Project and learn how to plan, draft, and edit reports, and how to give oral presentations of their work to an audience. Emphasis is given to the conventions of the English language – grammar, syntax and vocabulary – and to clear writing in a range of contexts. The involvement of the English Language and Communication lecturers in the Project subject provides students with an opportunity to obtain professional feedback on the content and style of project documents prior to formal submissions, and on oral presentations during trial runs.

In regard to future employment, the English subject introduces students to work-related skills including job applications, resumes, interview techniques, interpersonal skills, small group communication, and writing and speaking professionally. Students continue their work on the Project, while presenting the results of their work in written reports and oral presentations. Emphasis is given to the professional standard of their efforts.

Web ACE – The Informing System Perspective

Among the three components of the Informing Science framework (the informing environment, the delivery system, and the task-completion system), the task-completion system is the one that determines the creation of the other two; it specifies the task that needs to be accomplished and, in turn, the task defines the required information (Cohen, 1999). In this instance, there were three distinct tasks:

1. To *design* an online system (Web ACE) to help two groups of clients with the English subject: one, future Project students enrolled in the subject; and two, English teachers involved in its delivery. The information required to accomplish the task was twofold as well and included: one, curriculum of the English subject (provided by the English teachers – informers at this stage); and two, information about system features that could improve the realisation of the curriculum and better support the teachers (provided by the Project team students – informers at this stage). Thus represents a design level activity in Cohen's (1999) framework.
2. To *construct* the Web ACE system. This represents instance creation, in Cohen's terminology.
3. To *operate* the Web ACE system. This represents Cohen's (1999) informing instance, and involved the communication of English-language related subject matter.

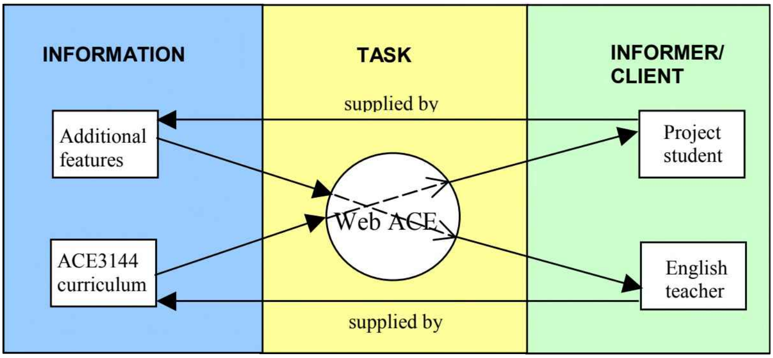

Figure 1: Web ACE task-completion system

The details of the Web ACE task-completion system are depicted in Figure 1. Although the same participants were involved at all three levels, the flow of information differed significantly over time.

During the design stage communications flows would be bidirectional, with both students and teachers taking on roles as informers and clients. During the instance creation stage, the students would act as the

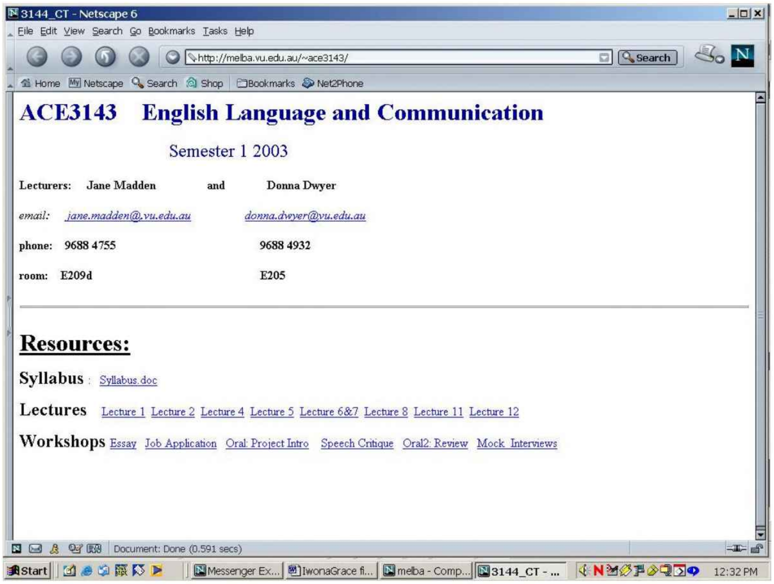

Figure 2: The old Web site for the English Language and Communication subject

principal informers (the communication would flow from them), letting teachers know about the features they were implementing and driving the process. Finally, upon completion of the system, the directionality of the flows would reverse, with teachers becoming the informers (communication generators) and students becoming the clients; at this stage Web ACE would serve as the channel through which information was transmitted.

Web ACE – The Development

For several years, prior to the development of the Web ACE system, information on the English Language and Communication subject and course material was provided to students via the Internet on the subject's Web site. The Web site, depicted in Figure 2, was very basic and poorly structured; its layout seemed awkward – links to subject material were organised horizontally across the page – hindering navigation; it was impossible to distinguish between new and old information; and there were no links to related subjects, nor any links to useful resources. Moreover, the Web site was maintained not by the English lecturers themselves, but by a third party. As a consequence, most of the time, the displayed information was outdated; even news on 'current' events reached the Web site after the events had occurred. These delays were unhelpful and annoying to the users. Indeed, to Computer Science students, the Web site was an example of 'how not to design and maintain a Web site', as it violated all the criteria of effective Web sites (Rathswohl, 2002).

Motivation

A paradoxical scenario has developed: on the one hand, professionals in the field of language and communication taught computing students new and valuable skills utilizing a clumsy information technology (IT) tool in the form of the subject Web site; and, on the other hand, budding computing experts, while appreciative of the new language and communication knowledge imparted to them, grew quite frustrated with the antiquated subject Web site and felt that they, too, could 'teach' their English lecturers a lesson, in IT.

A group of three students felt so strongly about the matter that instead of selecting a project from the available list, they proposed a project of their own – the development of a new Web based system for the English subject. They believed that, as 'insiders' – both in their capacity as users of the existing subject Web site and IT 'professionals' at the same time – they were in a unique position to design and implement a new informing system that would be functionally sound, user friendly, and easy to maintain by the English lecturers themselves. Having obtained approval from the Project Coordinator, the students approached their English lecturers with the offer. The lecturers, somewhat surprised with the students' initiative, agreed. This was the beginning of Web ACE.

Analysis and Design

The new system needed to satisfy two main objectives. Firstly, to enable the English lecturers to perform collective editing of subject material in the back-end of the system, and to facilitate subsequent placement of the material on the students' Web site without the involvement of a third party. Secondly, to provide students with current subject material, instant feedback on assignments, links to useful resources, and the ability to interact with English staff and fellow students online. It was therefore apparent from the start that the existing static Web site needed to be replaced by a dynamically updateable content management system with a back-end managed by the English lecturers, and a front-end available to students.

The lecturers, thrilled as they were with the prospect of timely updates to the subject material posted on the Web site, met the idea with some apprehension. They were afraid that, with the third party removed, it would be their responsibility to write software code every time they wished to make the required updates to the Web site. Students dispelled their worries in an instant, explaining the 'obvious' to the 'technically challenged' English lecturers in a language that they could easily understand for example, that updating the content of the Web site would be as simple as sending an email. Interestingly, when asked about identifying requirements of the new system, the lecturers could not think beyond the scope and capabilities of the existing one. Here, again, the students came to the rescue and presented a list of possible requirements. The overwhelming reaction of the lecturers was an utter disbelief at the functionality and variety of presented options, as they repeatedly asked 'Can you really do that?' The system requirements were finalised during subsequent meetings and included facilities to: edit (collectively), upload and update subject material, news, and results; create and edit links to resources; manage staff information; and communicate with students. A 'frequently asked questions' (FAQ) list, help function, and an appropriate security mechanism were also included. Lecturers were also consulted regarding screen layouts and colour scheme for the system.

The other group of clients, the students enrolled in the English subject, also participated in the requirements collection process. They were asked to complete a survey detailing the proposed system; they stated their preferences regarding various facets of the system ranging from functions, through layouts, types of links and font sizes; they were also invited to identify any additional features that they wished included in the system. In addition, the existing Web site was evaluated using Jakob Nielsen's (2000) Useability Principles to identify its deficiencies and create suitable responses.

Having established and consolidated the system requirements, the students, in consultation with their supervisor, decided that the best approach to developing the Web ACE system would be to use Boehm's spiral model of the software process. That model involved four continuous stages of planning, analysing, designing and implementing, followed by evaluation of each iteration of the software process (Sommerville, 1996). The development team decided to use the Unified Modeling Language (UML) to specify, construct and document the architecture of the system (Priestley, 2000). Different 'use case' diagrams and scenarios were used to illustrate the sequence of events for the various system functions, for instance, logging in to the system, viewing students' results, uploading subject material by staff, and downloading of material by students. Other non-functional requirements such as user interfaces and useability, system performance with respect to downloading time, hardware options, maintainability, portability, and security were also defined and documented in the Software Requirements Specification (SRS) document (Sommerville, 1996).

The design phase, following the development of the SRS, consisted of three major activities: preliminary design of mock-up graphical user interfaces; design of system architecture; and, the detailed design of the entire system. Then, a prototype of the new system was implemented and presented to the clients for evaluation. The process was repeated, following the Boehm's spiral model, and each time the system was enhanced and refined.

Implementation

The front-end of Web ACE – the part of the system accessible to the students – was primarily coded in ASP, with HTML and VBScript linked with a Microsoft Access database. Coding has been completed in segments, with each system function, such as 'News', broken down into smaller functional modules, for example, 'Add News', 'Edit News', Delete News, etc. The code of these smaller modules was subsequently re-used in similar functional elements of other main functions such as 'Staff Information', 'Help' and 'Links'. The front-end Web site was implemented only after the back-end of system – the part of the system used and managed by the English lecturers – had been completed. This ordering of implementation steps was necessary, as the front-end relied heavily on data that could only be created through the back-end. Once both the front-end and back-end were up and running, testing of both subsystems could be conducted, and necessary alterations easily made, as the core code had been already established. The Web ACE prototype was repeatedly evaluated by the project team, the English lecturers, and the project supervisor. Ideas raised and recommendations made in these sessions were used to fix any existing errors, improve inadequate areas, and accommodate new user requirements. It is worth noting that the English lecturers were almost apologetic every time they wished that yet another enhancement be included in the system. In the process, they gained a whole new appreciation of the impact that such changes would have not only on the design and implementation of the software system, but also on system documentation and reports – the very assessment tasks required in the English subject.

Web ACE used a metaphor of a filing cabinet to help users find information, and navigate through the system in a logical manner. Helpful icons, resembling the tasks at hand, were used to create associations between the system and the real world. A site map was included to provide better control and ease navigation of the site. Aesthetic, minimalist, and functional design was applied to the Web interfaces according to criteria advocated by Rathswohl (2002), such as impression on first entry, inclusion of key fact in the homepage, consistency in the use of colour, usefulness of external links, etc. Error handling routines, including helpful error messages and alerts, were also incorporated in the system. For example, error messages were produced in case of incorrect data entry, or upload of oversized files;

and alerts were issued to require confirmation for deletion and modification of files, or make users fill in mandatory text fields.

Marketing

With Web ACE fully implemented, its creators decided that their software development effort would not be complete without proper marketing of the finished product. They were not satisfied with the prospect of presenting their system only during the final demonstration session – a requirement for all Project students. They decided that, as in the 'real' IT world, a marketing workshop, coupled with an acceptance test, was in order. The aim of the workshop was to showcase the system, provide a thorough step-by-step demonstration, and a hands-on tutorial session on Web ACE. Students designed, printed, and hand-delivered invitations to the workshop. The fourteen invitees included the English lecturers, the project supervisor, the Project co-ordinator, and a number of senior academic staff. The workshop was conducted in a suitably equipped laboratory with students projecting the demonstration from a PC onto a big screen. Workshop participants, armed with user manuals and logged into the system as super-users, replicated various demonstrated steps on their computers.

Web ACE creators took turns in presenting various aspects of the system. It was apparent that a great deal of thought and effort had gone into the preparation of the demonstration. It was well structured, well rehearsed, and well timed, with smooth changes between presenters. Demonstrating comprehensive knowledge of the system, presenters skilfully singled out its most impressive 'selling' aspects, and emphasised its advantages. After the presentation, they answered questions and asked for comments and recommendations; they also conducted a survey to obtain final feedback on the system to enable them to put finishing touches on the product before its delivery and deployment.

Evaluation

Web ACE has been regarded highly by its clients throughout its development; this view was further confirmed by the results of the workshop survey completed by fourteen participants. The survey was divided in two parts. The first part evaluated various facets of the system ranging from accessibility and efficiency aspects through helpfulness of on-screen instructions, and quality of screen layouts; a 5-

point Likert scale was used to measure the responses, with 5 indicating *strongly agree* and 1 indicating *strongly disagree.* The second part of the survey asked for comments regarding most useful and best liked system features, as well as suggestions regarding possible improvements and future enhancements.

The level of satisfaction with Web ACE, its Students' View depicted in Figure 3, was high, with an average score of 4.88. The features deemed most useful and best liked included the 'News' and 'Links' modules; the workgroup environment enabling collective editing of course material; the ease of adding new course content to students' Web site; uniformity of interfaces and accessibility of various menu options; and speed of uploading and downloading files. Suggestions of possible improvements and enhancements included minor rearrangements of menu options, for example upgrading 'Results' to a main option and removing it as a subsection of 'Subjects'; renaming 'Help' to FAQ to reflect better the true nature of the system feature; marking mandatory fields with a star (*); and, greying out inaccessible read-only information. The best summary of the Web ACE effort was a single comment on one of the surveys: 'Well done!'

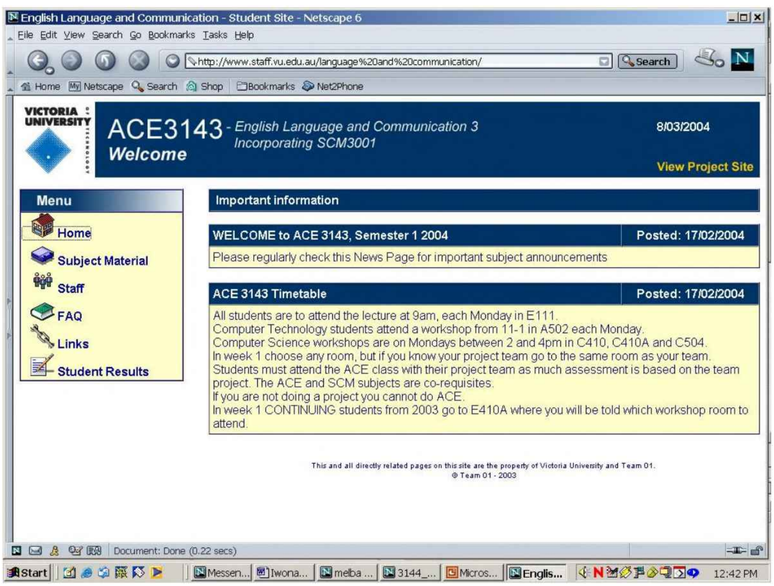

Figure 3: Web ACE – Students' view

The value of Web ACE and the skills of its developers were given one more vote of confidence – they were turned into an example of good practice to be used with future generations of Project students. This was accomplished in three ways; firstly, Web ACE was immediately deployed, and has been operational ever since; secondly, the documentation generated by the development team in the course of the Project was included as reference material in the English subject; and thirdly, the students' performance in the 'marketing' workshop was videotaped for use as demonstration material in the subject.

Conclusions

This chapter described the inception and implementation of Web ACE, a Web based content management system developed by Computer Science students, in their final year Project subject, for an unusual group of clients – academics from the department of English Language, Communication and Cultural Studies. Those clients were also involved with the Project students in a different capacity – as their lecturers providing service in the English Language and Communication subject. This unique scenario created two platforms for client/informer, or learner/teacher, engagement whereby each of the parties involved played the role of clients/learners on one platform, and the role of informers/service providers on the other. On the English language and communication platform, the English teachers played the role of informers, and the students were the learners. However, on the computing platform the roles were reversed, the students informed (provided service), and the English teachers learned. The fact that the teachers were not the only source of knowledge in the universe of the Project was very important. It created an implicit understanding that teaching and learning was a shared responsibility, and that teachers were also open to learning. As a result, a more horizontal process of interaction developed between teachers and students.

The Web ACE experience yielded a number of benefits: student developers gained confidence in their real-life computing skills and appreciation of good communication skills; English teachers gained respect for the students' computing skills, and saw the positive impact of extra motivation and well directed encouragement on the students' communication skills; and, most importantly, future Project students will benefit not only from using Web ACE, but also from working with

English lecturers who have acquired a better understanding of the difficulties faced by students developing real-life computer systems.

The conceptualization of education as an informing discipline and students as clients to be informed brought a desired focus on students and the learner-centred learning but still left clients – students – on the receiving side of information and the teacher in the role of informer – server. However, just as the distinct roles of clients and servers in computer networks have undergone a significant transformation in recent years in that clients also provide information and servers request and receive it, a similar transformation can be applied to education and the Web ACE scenario illustrated in this chapter is a case in point.

Viewing the Web ACE development from the informing science perspective encouraged reflection on one key component in particular: the task completion system. While the task that needed to be accomplished was to create a system to help future Project students, the system was meant to help the English teachers at the same time; this was an important realization that helped define the information that was needed to accomplish the task. Both the English teachers and the Project team students played the role of information providers: the teachers specified the English subject curriculum requirements; and the Project team identified additional system requirements that would enhance its quality and operation.

The application of the informing science framework to the Web ACE development process was found very helpful. As a result, it was decided that the framework would be used in the delivery of the Project subject to help students conceptualize, design, and implement computer systems that would best inform their clients.

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Chapter 20

The Role of Informing Science in Establishing Research Context: An Integrated Model of Collaborative Knowledge Building Process

Gurparkash Singh, Louise Hawkins, & Greg Whymark

Introduction

Collaborative knowledge building (CKB) refers to collective work for the advancement and development of knowledge artefacts (such as theories and concepts) (Paavola, Lipponen, & Hakkarainen, 2002). Current studies in CKB focus on the processes involved by which a group of participants come together and create knowledge. The focus of the studies has gradually shifted from analysing learning outcomes (Lipponen, Hakkarainen, & Paavola, 2004) and studying effective conditions for collaborative learning (Stahl, 2006) to understanding the underlying processes involved by which groups create knowledge in the context of an activity (Dillenbourg, Baker, Blaye, & O'Malley, 1996). Dobson and Gros (2001) argue that for furthering an understanding of the CKB process requires research methodologies and frameworks that highlight and at same time explain the role of context in CKB. This aspect is also noted by Arvaja (2007) who argues for studying the CKB process within the broader social context in which the group activity takes place.

Existing studies in CKB have been criticised for neglecting the broader social context and activity in which collaboration is embedded (Arvaja, 2007; Crook, 2000). There is a lack of research tools and frameworks that help in establishing and describing the context within which CKB process is embedded. In this chapter we draw on the Informing Science Framework (ISF hereafter) for addressing this major shortcoming of the existing studies in CKB. The ISF is used in this chapter as a lens for establishing the context within which the process of CKB is embedded. Our motivated activity for this chapter is to provide a means of informing other researchers and practitioners about how we draw on cultural historical activity theory and the ISF to describe and assist people in knowledge building activities.

As a lens, the ISF is used to develop the context for conceptualising the CKB process using cultural historical activity theory constructs. Cultural historical activity theory (CHAT) constructs provide rich description of the context. Our aim is to show the many commonalities between the ISF and CHAT through the discussion of a knowledge building process, and how ISF combined with CHAT provides for a richer method.

CKB is a cyclical and a transformative process whose outcome is the creation of knowledge artefacts (such as models, problem resolutions, innovative practices) (Stahl, 2006). In other words, the process of CKB transforms (or moves) through the following sub-processes:

1. Participants articulating and sharing knowledge about a topic or a problematic situation,
2. Refinement of the articulated knowledge using collaborative reflection as a tool at the group level,
3. Discussion of different perspectives for achieving shared understanding, and
4. Creation of knowledge artefacts (Singh, Hawkins, & Whymark, 2008).

These transformations unfold cyclically in space and time and are representative of the dialectical relationship between the individual and group level processes in CKB. For example, one of the authors facilitated a group activity whose subjects were a group of academics working on a research project. The object of the research project was to share assessment related issues and practices within a university context. The group had two sessions. In the first session each participant's viewpoint and knowledge regarding specific research questions was captured using a groupware. In the second session, the group developed common themes from the data they had gathered in the first session. The common themes were developed through discussion of ideas, and consensus at group level. Both the sessions used ZingThing®™ groupware as a tool for capturing ideas, and the themes. The outcomes of the two sessions included the generation of rich qualitative data, a theme based group data analysis, and knowledge constructed by the group. These outcomes were preserved in the groupware. Secondary outcomes also included learning and knowledge gains at the individual level (Singh et al., 2008).

In the preceding example, the object of the group activity was gathering and analysing data for the completion of a research project. The outcome of the two group activities was the generation of knowledge regarding assessment practices, i.e. innovative ways of improving existing practice. This resultant knowledge was created collaboratively by working on a shared object. Participants at the individual level articulated and shared knowledge, and at the group level different perspectives were discussed, challenged and improved, resulting in building of knowledge.

CKB is a socio-communicative process (Stahl, 2006) involving individual and group level processes. Based on the evidence from our own constructivist teaching strategies and current literature on CKB, we present an initial study undertaken as part of investigating and documenting the CKB process. The study also explores the role of reflective thinking and collaborative reflective discourse in helping participants achieve a shared understanding as part of the CKB process.

In examining the CKB process, we employ two frameworks: CHAT and the ISF. CHAT has provided us with a means of analysing the interaction of these processes as part of the CKB process. The Informing Science framework adds another dimension to this analytical power, by drawing our attention to the three interacting systems of informing environment (i.e. the analytic level of interactions at group and individual level) to the, task completion system (i.e. problem domain and object of activity) and to the delivery system (ICT tools used in the process) (Cohen, 1999).

Collaborative Knowledge Building

The concept of collaborative knowledge building (CKB) was introduced by Scardamalia and Bereiter (1994) in their study of learning at school, in which they proposed that schools should function as knowledge building communities. Knowledge building refers to collective work for the advancement and elaboration of conceptual artefacts (Paavola et al., 2002). This knowledge building approach and knowledge building process aims at facilitating collaborative work for sharing and advancing knowledge artefacts (Scardamalia & Bereiter, 1994). CKB is conceptualized as a social process in which participants co-construct knowledge through social interactions (Lipponen, 2002; Stahl, 2000).

Disagreement still exists regarding the nature and process of CKB. Even though considerable theoretical contributions towards understanding CKB have emerged (Hmelo-Silver & Barrows, 2008; Stahl, 2006), there have been few detailed attempts to model the underlying sequence of activities that result in co-creation of knowledge artefacts. Recent studies in CKB focus on exploring the distributed nature of knowledge building in a collaborative context (Aalst, Kamimura, & Chan, 2005), identifying conditions necessary to support knowledge building communities (Gilbert & Driscoll, 2002) and identifying knowledge building indicators (Lipponen, 2000). However it is not yet clear as to how participants articulate knowledge, develop shared understanding, the nature of mediating tools used by participants and the role of context in the knowledge building process.

The process of CKB and the sub-activity of achieving shared understanding moves through a constant cycle of building and breakdowns in meaning making amongst the participants. The participants interpret meaning and develop shared understanding by constantly interacting with each other using language and jointly constructed artefacts. The case study presented here further explores the use of reflective thinking and collaborative reflective discourse as mediating tools for achieving shared understanding and articulating tacit knowledge as part of the CKB process. Our intention is not to refute previous work, especially within the field of knowledge management, regarding tacit knowledge, and to what extent it can be articulated (Refer Leonard & Sensiper, 2000; Von Krogh, Ichijo, & Nonaka, 2000). Rather the focus is on understanding the ways by which knowledge articulation occurs in authentic group-work contexts—contexts built around tasks that:

1) have real-world relevance and utility,
2) are poorly defined (i.e. participants have to identify problem and the sub-tasks needed to complete the activity),
3) provide participants with an opportunity to examine the activity from different perspectives,
4) provide opportunity for collaboration,

5) result in development of diverse solutions (i.e. open to multiple solutions with no single correct answer) and

6) provide opportunity to reflect (individually and socially) (Herrington, Oliver, & Reeves, 2003)

Thus tacit knowledge is conceptually viewed as occurring on a continuum with – tacit knowledge on one end and collaboratively created knowledge at the other. The focus is on trying to better understand the process by which knowledge is articulated in group work context, and the tools (physical and conceptual) which mediate this process.

The paper develops a theoretical model for CKB process by modifying Stahl's (2000) model of CKB, draws on the ISF to establish context, uses constructs from thinking theory to explain how participants inform each other, while drawing on CHAT (Engeström, 2001) to analyse the data. The theoretical support for Stahl's CKB model, apart from other perspectives, focuses on group and personal perspectives, learning and knowledge building being mediated by physical and symbolic artefacts , and internalisation of cognitive artefacts (Stahl, 2002). These perspectives are consistent with the basic constructs of CHAT.

Bringing it Together: Contributions of Different Theoretical Frameworks to Study CKB

The rationale for using the above mentioned theoretical frameworks for furthering an understanding of the CKB process is supported by the contribution made by each of the frameworks. The ISF framework draws our attention to the three interacting systems (i.e. informing environment, task completion system and the delivery system) that help in developing and explaining the context of the study, and analysing the dialectical relation between them. CHAT is compatible with CKB, as they both take as their unit of analysis the group activity. In order to reach a shared understanding, the group must work through a number of breakdowns, as individuals present and explain their meaning and others question these meanings. Within CHAT, breakdowns are referred to as contradictions, which are defined as "historically accumulating structural tensions within and between activity systems and are not the same as problems or conflicts" (Engeström, 2001, p137). Identification of contradictions within a dialogue provides the researcher with a method of showing how the contradictions transform the group activity. Transformation of the activity leads to a more culturally advanced activity. A culturally advanced activity is the transformed version of the current activity which attempts to improve the activity by dealing with some of the internal problems of the current central activity (Hawkins & Whymark 2006).

CHAT is compatible with the ISF, as they both allow the consideration of parts of the whole activity without losing the richness and complexity of the context. Another area of compatibility is being able to consider the implications of changes in one area of the system with neighbouring activities, i.e. how the changes in the informing environment affect the composition and nature of the task completion and delivery system. Constructs from reflective thinking theory help in explaining the nature of the CKB sub-activities of articulating knowledge and developing shared understanding. Taken together, these frameworks help in developing an integrated model of the CKB process which is presented and discussed at the end of the analysis.

To achieve the research aim the following research questions are examined:

- What is the role of collaborative reflective discourse in collaborative knowledge building process?
- What is the relation between reflective thinking and collaborative reflective discourse in context of CKB?

The next section discusses the underlying theory of CKB based on the knowledge creation metaphor of learning. It also provides a rationale for studying reflective thinking as part of CKB process. This leads to the section in which the relevant concepts from the ISF are introduced. The section on the case study provides a background to the case being examined and conceptualises CKB as an activity system using Cohen's (1999) three interacting systems of the ISF. The section on unit of analysis explains how the ISF helps to establish the context of the study and discusses the constructs of CHAT that are helpful in analysing the process of CKB.

The section on data analysis focuses on the third level of the informing system, i.e. the level of building knowledge and models for explaining knowledge building process. Data analysis is divided into three phases. Phase 1 analyses the use of reflective thinking as a tool for articulating knowledge and discusses the role of individual reflective thinking for articulating tacit knowledge and conceptualising artefacts. Phase 2 describes how participants engaged in collaborative reflective discourse to develop a shared understanding. In Phase 3 the participants used the outcome from the previous activity (i.e. shared understanding) to collaboratively build knowledge. Based on historically sequencing of the transformations in the CKB activity system, phase 3 presents an integrated model of CKB.

Underlying Theory of Collaborative Knowledge Building

Researchers have studied CKB in different fields (such as education, computer supported collaborative learning, knowledge management, organisational learning) and contexts such as, higher education and university environments (Stahl, 2006), schools (Hewitt, 2004), human resource and professional development (Tillema, 2005, 2006) and workplace learning (Dobson & Gros, 2001; Engeström, 2008; Owen, 2001). The growing emphasis on CKB is due to group-work becoming highly pervasive in organisations (Akkerman et al., 2007), the identification of the benefits associated with collaborative learning (Roberts, 2005), and the recognition of a limited individual cognitive ability to tackle complex problems (Lehtinen, Hakkarainen, Lipponen, Rahikainen, & Muukkonen, 1999).

Currently there are range of views that attempt to theorise about the learning and knowledge building potential in groups (Scardamalia & Bereiter, 2006). Paavola et al (2002), in their review of the theories used by researchers in studying learning and knowledge building, identified three metaphors of learning - namely *acquisition*, *participation* and *knowledge creation* (Table 1). These three metaphors of learning represent basic ways or 'ideal types' for understanding knowledge building.

As we can see from Table 1, the theoretical framework adapted by a researcher for studying CKB has implications in terms of answering questions such as who the learner is, how knowledge building is conceptualised, and what method to use for investigation. The knowledge creation metaphor of learning, in particular, attempts to go beyond existing theories on knowledge building (such as the ones used in acquisition and participation metaphors of learning), by drawing attention to the collaborative and contextual aspects of knowledge building. CHAT and concepts from ISF provided us with the means of operationalising the constructs from knowledge creation metaphor of learning by emphasizing:

(1) The dialectical relationship between individual and group level processes in CKB.

(2) The mediating tools used by participants at the individual and group level and the relation between individual and social aspects of knowledge building.

(3) Holistically tracing the development of knowledge artefacts by analysing how group activities unfold sequentially in space, and time, and

(4) The context in which the group activity is embedded (i.e. the nature of the task, problem domain, shared objects of activity and the wider socio-cultural context in which the activity unfolds).

The genesis of new knowledge constructed jointly by participants in a collaborative environment can be explained by the knowledge creation metaphor of learning (a pedagogical approach) (Paavola et al., 2002) and the collaborative knowledge building model (pedagogical model) (Scardamalia & Bereiter, 1994; Stahl, 2000). The knowledge creation metaphor provides a theoretical base by which the CKB model can be understood, applied and explained. Knowledge building involves production and continual improvement of ideas which are of value to a community (Scardamalia & Bereiter, 1994). Within a community the ideas can be considered as conceptual artefacts that can be examined and improved on by means of public discourse. The knowledge creation metaphor of learning conceptualises knowledge advancement and learning as a collaborative process for developing shared objects of activity which can only be accomplished by participating in cultural practices and by becoming members of knowledge communities (Paavola et al., 2002).

Conceptualising CKB as a social process suggests the examination of the process as an activity system (using CHAT), to be discussed later in this paper. But the question or the problem that needs attention is how participants develop shared understanding and are able to co-create knowledge. Documenting these underlying processes may help in the design of possible technological scaffolds to support the process of CKB.

Table 1: An overview of the three metaphors of learning (Adapted from Akkerman et al., 2007; Paavola et al., 2002)

	Acquisition	Participation	Knowledge creation
Research focus	Individuals as autonomous agents who acquire & construct knowledge. Mind as a container of knowledge, & learning is a process of filling up the container with knowledge.	Individuals learning to become members of communities. Learning situated in social & cultural contexts. Individual agency is acknowledged, but learning is situated in participation processes.	Groups working collaboratively on shared objects to create knowledge artefacts. Individual learning is a result of participating in group activities (a secondary aspect)
Theoretical foundations	Cognitive theories, mental models, shared mental models (Cannon-Bowers & Salas, 2001; Driscoll, 2000; Johnson-Laird, 1983)	Constructivist - Socio-cognitive conflict (Oshima et al., 2006; von Glaserfeld, 1989) Situated and distributed cognition, communities of practice, socio-cultural theory (Bonk & Cunningham, 1998; Lave & Wenger, 1991; Vygotsky, 1930/1978)	Knowledge building theory and principles (Scardamalia & Bereiter, 2006), cultural historical activity theory (Engeström, 2008)
Unit of analysis	Individuals	Groups, communities	Multi-level analysis of individual & group level processes, & wider context of group activity

Method	Laboratory experiments, pre-post tests, aggregated data to show similarity/overlap of mental models	Ethno-methodology, discourse analysis, conversational analysis	Research in close collaboration with participants in authentic contexts of group-work
Collaborative knowledge building	Individuals coordinate knowledge stored in mind. CKB interpreted as overlap or similarity between mental models of individuals	Process of participating in meaning making activities & developing a shared understanding through interaction with the group level interactions constituting the knowledge	Collective work for advancing knowledge artefacts while working on intentional & authentic activities. The activities are aimed at fulfilling a mutual objective, i.e. shared object, which mediates the activity

Stahl (2000) in his study of CKB breaks down the process into a number of important phases including cycles of personal understanding and social knowledge building. His model for the CKB process stresses the need to focus on group activities and notes the importance of conceptual artefacts. According to Stahl (2001) CKB is a process of communication where groups of people construct new knowledge through interaction of their ideas and perspectives and is preserved in artefacts (conceptual or written documents). In order to build new knowledge, the informing environment needs to develop new processes to build knowledge, i.e. focus on the third level of building knowledge (see Figure 1). The meta-systems analysis approach within the ISF is a useful concept when considering the CKB process. At the first level we can consider a group of people engaged in collaborative knowledge building. The next level of abstraction allows the consideration of the facilitator planning the CKB process. While at the third level of abstraction, researching the process of collaborative knowledge building can be considered. The CKB process, or the way knowledge is built and shared is described as a "synergistic moment" (Stahl, 2000a) by which the group reaches a shared understanding by participating in the socio-cultural process (Stahl, 2001). Each member of the group brings their personal perspective and interpretations of experiences.

The process by which a group reaches shared understanding and inter-subjectivity through constant interactions is broken down into smaller knowledge building activities within Stahl's model.

Role of Reflective Thinking in Collaborative Knowledge Building

Aalst and Hill (2006) propose self monitoring of knowledge as an important characteristic and capability that needs to be promoted to develop support for participants in CKB processes. Self-monitoring involves a meta-cognitive understanding and an insight into one's own learning process. Engaging in reflective thinking can be a useful way of explicating tacit knowledge (Tillema & Van der Westhuizen, 2006), internalizing newly acquired knowledge (Kim & Lee, 2002), and facilitating knowledge construction (Andrusyszyn & Davie, 1997). Many researchers (Mayer 1991, Tishman, Jay, & Perkins 1993 as cited in (Baker & Lund, 1997; Kim & Lee, 2002) have identified that reflective thinking (meta-cognition) is an important capability that needs to be cultivated in learning and knowledge building situations. For the purpose of this paper, reflective thinking is described as an active thinking process for monitoring one's own learning process to bring about effective conceptual change.

More recently researchers have started exploring the social aspects of reflective thinking. For example Yukawa (2006) in her study of online group action research provided evidence of the potential of collaborative reflection as a core process in group learning. Collaborative reflective discourse serves to make one's experience and viewpoint visible to peers for the purpose of getting a different perspective. Lin et al (1999) highlights three benefits for collaborative reflective discourse: (a) increased interaction between participants, (b) reflection is more motivating when there is a public audience, and (c) reflection helps ideas and thoughts to become artefacts or objects for further reflection. In this chapter we present the results of an ongoing research on the role of reflective thinking activities in the CKB process.

The premise being investigated is the notion of reflective thinking and collaborative reflective discourse being used as mediating tools in the CKB process (Singh, Hawkins, & Whymark, 2007). The understanding of these underlying processes would help in documenting the process of CKB and developing a theoretical model to explain the process. Having established the rationale for examining the role of reflective thinking and collaborative reflective discourse within CKB, the next section briefly introduces the concepts from the ISF relevant to this study.

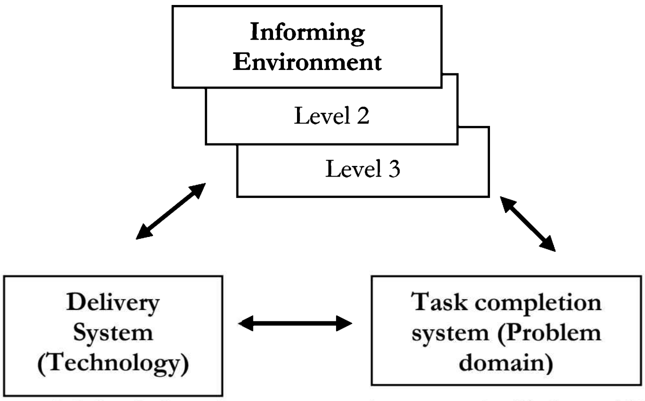

Figure 1: The informing science framework (Cohen, 1999)

The ISF framework

In this section we briefly re-visit the relevant concepts from the ISF based on Chapter 2's (Cohen, 1999) conceptualisation of the informing environment. "Informing science as a discipline emerged as a result of the observation that many disciplines like education, library science, information systems were studying the movement of information between senders and receivers in ways that were far more similar than they were different" (Gill & Bhattacherjee, 2007, p18). Cohen (1999) defines informing science as a transdicipline with the aim of providing the clientele with information in a form, format and schedule that maximizes its effectiveness. The framework includes three interrelated components: the informing environment, the delivery system and the task completion system (Figure 1). The informing environment includes three levels of abstraction: 1) level at which actual informing occurs 2) level at which new informing instances are created and 3) level at which overall designs for such systems are specified (Gill & Bhattacherjee, 2007). These three levels of the informing environment helped in identifying and studying the relevant levels of abstraction in the CKB process.

This study focuses on the three levels of abstraction in the informing environment. The next section describes the educational context from where data was gathered and then uses Figure 1 to develop the context and unit of analysis for the study. This is achieved by operationalising and identifying the task completion system, means of technology used and conceptualising the informing environment levels. The three levels of abstraction in the informing environment are related with the case study activity of the subjects (i.e. the participants' tutorial planning activity) to establish the context and the unit of analysis. The next section describes the case study and the participants' group activity.

The Case Study

This is not a traditional empirical case study. The data comes from a recorded collaborative problem solving session (one of many), where the objective was to design teaching material and strategies to achieve certain educational objectives. It happened to be recorded for the benefit of the teaching staff member who had to implement the outcomes. As the session used a product called ZingThing®™ (hereafter called Zing) to facilitate brainstorming and other collaborative activities, much of the output was recorded within the product and was available after the session. The participants included the authors to this paper. The case study could also be presented as an example of reflective self assessment of teaching practices.

However, after the event it became apparent that the session, serendipitously recorded in all detail, could also serve as a tool in another concurrent task which involved research into CKB processes (Singh & Whymark, 2006). Thus the collaborative session described here is a truly authentic task, and as such is an ideal vehicle for the purposes of this paper. The conflict of the authors conducting the analysis also being involved in the case is acknowledged, but we believe this has had no affect on the analysis. One limitation is that the participants held known viewpoints on collaboration and participatory knowledge building, but we do not believe this impedes the purpose of this paper.

The physical circumstances of the case are now described. The phenomenon under investigation is the role of collaborative reflective discourse in the CKB process. The context is a group of participants working together in a joint activity to design tutorial activity for a post graduate course. The group participants (P1, P2 & P3) are part of a teaching faculty and research group focusing on knowledge management and group activities. Participant 1 (P1) is an associate lecturer with research interest in CSCL. Participant 2 (P2) is an associate professor with years of experience in research associated with knowledge management and Participant 3 (P3) is a lecturer with research focusing on facilitation of groups.

The tutorial activity being considered and planned by P1, P2, and P3, involves students using Zing groupware (refer to the Appendix for description) to discuss course concepts and is based on the pedagogy of collaborative learning and reflective thinking. The activity involves students brainstorming on a particular theoretical concept selected from the course and listing as many ideas as possible using Zing. During the evaluation phase, each idea is presented to the group for analysis and discussion. Students then need to identify as a group the categories emerging from the ideas and develop a summary statement of the category explaining the concept. The tutorial activity is based on the principles of social constructivism (Bonk & Cunningham, 1998), which involves students being responsible for their own learning, multiple perspectives being discussed, knowledge construction, collaboration, and authentic problem solving.

Zing as a groupware allows participants to work on a mutual task. Each group member has an assigned space for generating ideas. The generated ideas are transferred to a group space through special command key for the entire group to view the ideas. Thus the groupware allows participants to simultaneously generate ideas and engage in discussion, with the groupware mediating the group's activity. All the ideas are captured in the groupware allowing for the generation of a report which can be used later for analysis.

P1, P2 and P3's activity was to design and refine the tutorial activity described above (i.e. the 3 participants were planning a tutorial activity in which the question "what is knowledge" was used as an example). The analysis focuses on how the 3 participants (P1, P2, and P3) designed the tutorial activity, and engaged in discussion to develop a shared understanding about the tutorial activity. The data was gathered by digital recording of the face-to-face interactions of the participants, via observation and from the interaction report generated by Zing groupware. Analysing the group discussion supported the investigation of the role of reflective thinking in CKB process and helped to explain the role of context within which the group activity was embedded. The next section describes how the unit of analysis was developed to analyse the group activity using CHAT constructs.

Unit of Analysis

CHAT is a descriptive theory of human thought and behaviour within the context of a specific activity. This theory suggests that learning and knowledge building needs to be considered as an activity system that involves subjects and mediating artefacts (cognitive, physical) that act to transform particular objects of activity to achieve an outcome. Activity theory offers a framework for describing the activity, as well as provides a set of perspectives on practice that interlink the individual and the social (Engeström, 2001). Activity theory as a tool has been used by researchers in studying a wide range of activities, including human computer interaction (Kuutti, 1996), develop computer supported co-operative work tools (Kuutti & Arvonen, 1992), and analysing innovative learning in work teams (Engeström, 1999). Activity theory is used in this study as a descriptive and an analytical tool that helps in analysing the group interactions. Learning and knowledge building in CHAT is seen as a situated and social activity interlinking the individual and group level (Nardi, 1996, as cited in Johri, 2005).

In his studies using activity theory Engeström (Engeström, 1999a, 2001) provides a descriptive model for capturing, analysing and presenting activity based data. His activity system model is suited to study CKB process as learning and knowledge building is considered to be an activity system that involves subjects and mediating artefacts (cognitive, physical) that act to transform particular objects of activity to achieve an outcome.

The CKB Activity System

In this section we draw on the constructs of CHAT to conceptualise the participants' activity as an activity system for the purpose of data analysis. Conceptualising participants activity as an activity system involved identifying the following elements from Cultural historical activity theory and mapping them onto the activity system structure: subject (the 3 participants), object (develop tutorial activity for students), tools (language and Zing), rules (principles of social constructivism), division of labor (P1 presenting the tutorial activity, P2 & P3 assessing and refining the activity, and community (3 participants, wider teaching community). Figure 2 shows the participants' activity system as a set of interrelationships between the elements of the activity system.

The language provided by activity theory facilitates rich description of

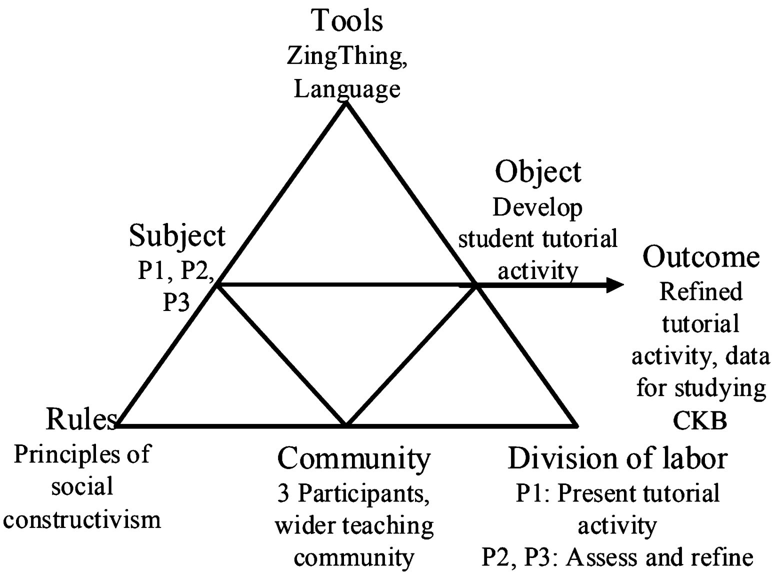

Figure 2: Tutorial planning activity

the participants' activity and conceptualising it as an activity system. According to Engestrom the object of the activity is related to production or what is being transformed into the outcome (as cited in Kaptelinin, 2005). The object of the activity in this case is concerned with the planning and designing of a tutorial activity by the group.

The object of the activity for subject P1 is to present a tutorial activity to the group. The object for P2 and P3 is to assess and refine the tutorial activity interactively with P1. Activities of P1, P2 and P3 are planning the instance, which is the second level of informing environment. Designing a tutorial activity is therefore at the second level of informing. The CKB model developed is at the plan creation level (3rd level of the Informing environment) as the study investigates the how's and why's of creating new plans, that is collaborative knowledge building.

Using the ISF (Figure 1) and Cohen's three levels of informing, we conceptualise the participants' tutorial planning activity as three interacting and interrelated informing systems to establish the context and the unit of analysis for of the study. In doing so we show how the

ISF and CHAT constructs help in developing the context of the study and the commonalities between the two frameworks. Identifying activity systems at different levels of abstraction allows researcher to identify the correct contextual level needed for analysis (Whymark & Hawkins, 2005). A clearer understanding of the purpose of each activity, which is important in CHAT, is also available when incorporating ISF concepts as activities at the three levels of the informing environment. Each of the three ISF systems were conceptualised as an activity system using elements from CHAT.

The task completion system includes the students using tutorial activity to achieve educational objectives and covering the course content. The delivery system is the technology being used for completing the task completion system. Zing groupware is being as a tool for achieving the object in both the task completion system and delivery system. The informing environment shows the three levels of abstraction of the case study. At level 1 is the motivation and the actual activity of the subjects (i.e. P1, P2 and P3) whose object was to develop the tutorial activity. The second level of abstraction is the process by which the subjects (i.e. P1, P2 and P3) developed the tutorial activity. This level corresponds to the process of creating new instances of knowledge and is the object of investigation for this study. Level 3 shows a shared vision of student tutorial activity which the 3 subjects are working towards. This represents the communal or shared object of the group. It is this shared object which directs the activity forward and mediates the process of creating new instances of knowledge at level 2. The data analysis focused on the transformations directed at level 2 which helped the subjects in creating the level 3 instance of knowledge building. Analysis also focused on identifying the contradictions between the three systems and what tools were used by the subjects (i.e. the 3 participants) in achieving their shared object.

Figure 3 depicts the planning activity system at a higher level of abstraction as compared to Figure 2. The rationale behind expanding the activity system was to:

1) establish a unit of analysis that documents the process of CKB (i.e. how the transformation from level 2 to level 3 of informing took place);
2) establish a flexible unit of analysis which helps the researchers to zoom in the analysis and identify the tools used by the

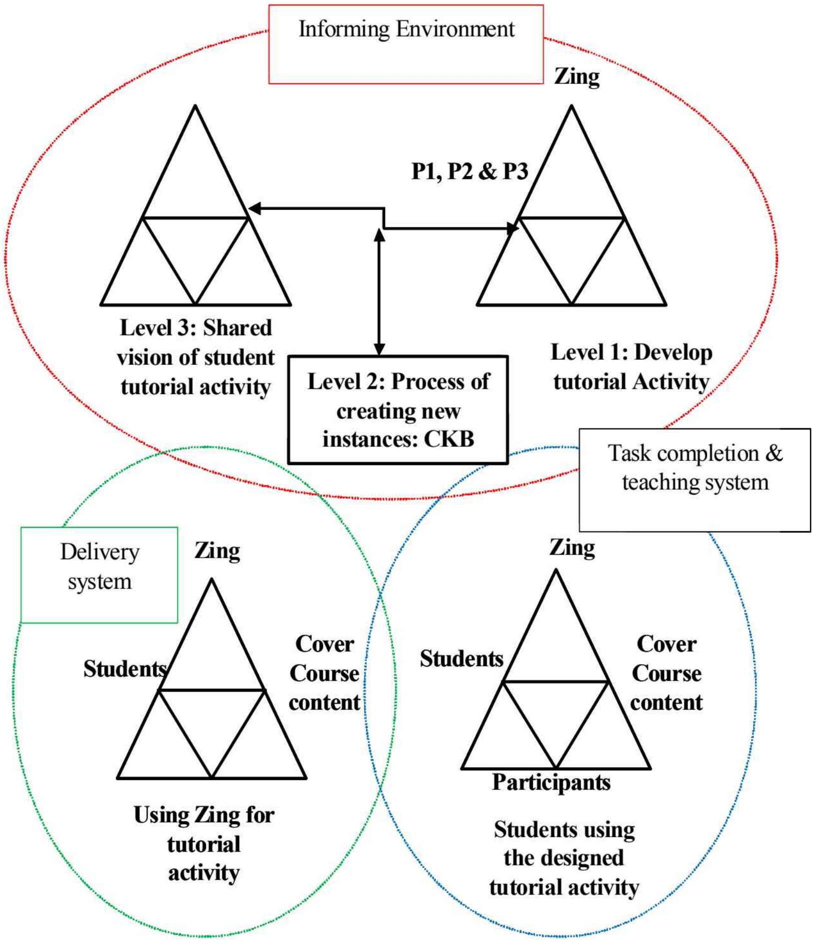

Figure 3 shows the relationship between the three interrelated systems of informing environment, task completion system and the delivery system.

participants to achieve their object at the individual and group level;

3) provide a description of the context without stripping it of its real life complexities, and

4) provide readers with a description on how the ISF concepts can be used and applied in research settings to provide a holistic and rich description of the context.

The context in this case involved the three participants working as a group to achieve their object. This context was used to study the process by which the group collaboratively built knowledge and to analyse the role of reflective thinking activities as part of the process. The ISF and CHAT together provide a useful analytical framework for analysing the data. The rationale for combining these two frameworks is based on the descriptive power afforded by each of the frameworks and the commonalities between them.

Interrelatedness is an important concept both within the ISF framework and within CHAT. Interrelatedness highlights that "…knowing can only be interpreted in the context of doing" (Jonassen & Rohrer-Murphy, 1999, p.64). Knowing by doing is similar to the ISF concept of "the inward-forming of a person that results from an engagement with data" (Boland, 1987 as cited in Cano, 2002). Understanding what is happening in a situation is enhanced when the interrelatedness between activities and components as in ISF and CHAT frameworks are combined. Components and systems within the ISF and CHAT models are interrelated as changes in one part of the system have repercussions across the system of activities (Cohen, 1999; Havnes, 2004).

The constructs of CHAT provide a useful and a descriptive framework for analysing group interactions taking the object oriented activity as a unit for analysis, in this case the designing and planning of a tutorial activity (Engeström, 1999). The depth of the descriptions provides insights into the different aspects of the activity being examined helping the researcher to focus on specific aspects, in this case the process and the mediating tools as part of CKB (Whymark & Hawkins, 2005). The third generation activity theory (Engeström, 2001) takes interacting activity systems as the unit of analysis that allows the analysis to zoom in and out at the personal and interpersonal planes (Rogoff, 1995). In other words it allows the researcher to focus the analysis at the individual and the group level.

Contradictions Driving Collaboration

Language has been described as the tool of tools (Vygotsky, 1930/1978), as it is a tool that once mastered allows individuals to communicate with each other regarding issues in the past, present, and future as well as the discussion of virtual conceptual entities. Language also allows an individual to engage in intrapsychological conversation, as language is used by an individual to 'talk to themselves'.

Within a conversation, contradictions in understanding are constantly being identified and resolved as individuals work together to reach a shared understanding of the topic under discussion. Contradictions are "historically accumulating structural tensions within and between activity systems" (Engeström, 2001, p. 137). Contradictions need not be seen negatively but as "driving forces" and opportunities transforming the activities (Whymark & Hawkins, 2005). "To develop means to resolve or transform these contradictions (instead of merely shifting them elsewhere) " (Nelson & Kim, 2001, p.4), and it is this change in the activity system that we identify within the data. In order for transformation to a culturally advanced activity to occur, the individuals involved need to be able to openly critique each others contributions and reflect on their own understanding. A culturally advanced activity is one that has transformed into either an expanded activity (with more possibilities and expanded object of activity) or a contracted activity (with fewer possibilities and a reduced object of activity (Hawkins & Whymark, 2006). Therefore it is the object of an activity that can be used to determine and map the advancement of an activity.

When the activity being undertaken involves reaching a shared understanding of a future proposed activity, dialogue allows for the consideration of how different decisions could potentially impact the achievement of the object of the proposed activity (Hawkins & Whymark, 2005). Identification of "contradictions seem to be a natural medium for mediating the connection between descriptions of (current) work and requirements on a new formulation of that work" (Turner & Turner, 2001, p.2), which in turn, increases the participants shared understanding.

CHAT is used here to explain what happened in the group dialogue, and to show how the activity under investigation was transformed as contradictions were raised and resolved within the collaborative environment. The next section describes CHAT based method for analysing the tutorial planning activity (Figure 3).

Data Analysis

The data analysis began by considering and reconsidering the data and identifying object oriented activities (Yamagata-Lynch, 2003). The object of the activity is related to transformation or production into an outcome (Kaptelinin, 2005). Taking this approach allowed for historically sequencing the process of CKB in the described activity system. The unit of analysis for this study is the interacting activity systems shown in Figure 3. The data analysis described in the following section began by tracing the progression, transformation and expansion of the object oriented activities within the CKB activity system (Figure 3). The activity analysed here is part of a wider activity system of teaching and research as shown in Figure 3. The next step involved identifying the contradictions or attempts by participants to repair misunderstandings for developing shared understanding (Stahl, 2006). Stahl (2006) describes the repair as a form of socially shared group cognition that takes place through discourse (social interactions, gestures, pose etc.).

The analysis uses CHAT diagrams to document and show the transformations in the activity system. The diagrams help in historically sequencing the transformations in the activity system through different phases with each subsequent phase building on the previous one. Methodologically the study: (a) is purposeful and focuses on understanding and improving teaching practice, (b) is carried out in close collaboration with practitioners, (c) documents transformations, and (d) is guided by an awareness of a potential to develop a theoretical model of CKB process (Lipponen et al., 2004).

Phase 1- Reflective Thinking and Externalisation

The activity progressed with P1 describing (by showing on the Zing groupware) the processes involved in the tutorial activity. The statements in brackets denote actions taken by participants, within inverted commas are statements entered to or from Zing, the dots (……) denote small pauses in narration, and the numbers in brackets () next to statement by P1, P2 and P3 denote statement number. They are referred to within the explanations for cross reference.

> P1 (1): What we have over here is a group activity which the group engages in every two weeks using ZingThing. What they will be discussing over here will be, they choose a concept which is problematic and if they are not able to choose themselves, I will choose the concept. So the way it goes is.....
>
> Today we will discuss what knowledge is so it is the focus and the agenda is we all have to list what we mean by knowledge. Couple of ideas are already put it in...so if you want you can put in couple of more ideas.....and then we can go to the next step...

An initial contradiction in shared meaning occurred when P2 suggested that:

> P2 (2): we will talk to you later about writing questions (looking at screen showing questions)

Although this initial breakdown in the activity was not discussed at length immediately, the quote (2) itself is an illustration of P2 using reflection-in-action based on expertise and experience and articulating tacit knowledge. Reflection-in-action refers to active thinking over an ongoing activity to understand and analyse the situation (Kim & Lee, 2002; Schon, 1983). It involves carefully examining the current situation by contrasting and comparing it with past experiences and tacit knowledge. By actively evaluating past experiences in context of the ongoing activity P2 is able to articulate tacit knowledge and inform other participants about the practice.

This led to the development of a reflective conceptual artefact as a conceptual representation in the form of "writing questions" by the group participants. Bereiter (2002) defines conceptual artefacts as products or objects of thinking and reasoning that can be argued about collectively. This denotes development of common terminology and is represented in this case by participants understanding of what "writing questions" meant in context of the activity. Therefore, the reflective conceptual artefact can be defined as a metaphor explaining the development of an artefact by engaging in and using reflective thinking as a tool in the activity (Figure 4).

The process for developing reflective conceptual artefacts can also be explained by participants appropriating experiences and beliefs on an internal plane as a representational activity (Internalization) (John-Steiner & Mahn, 1996). These internalized reflective conceptual artefacts are then transformed or externalized (through communicative language, symbols etc) by the participants for CKB, the entire process being mediated by reflective thinking.

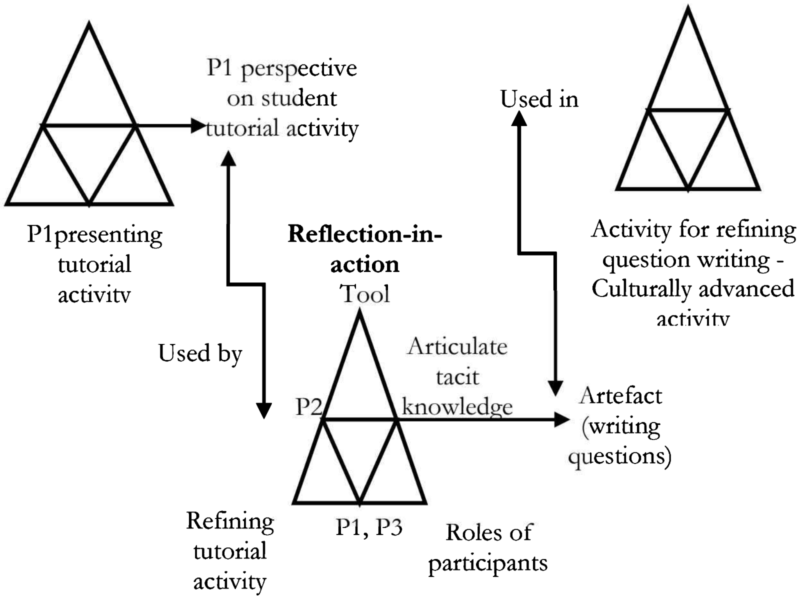

Figure 4: Developing reflective conceptual artefact

Reflective thinking is used as a tool to develop the artefact by P2 and it is then internalized by the group (Figure 4). The internalized artefact was externalized by P1 based on the common language and terminology developed by the group. It shows the importance of reflective thinking and reflective conceptual artefacts as mediators of developing shared understanding and articulating knowledge at the individual and group level. It also shows the mediating nature of reflective conceptual artefacts in the process of CKB in terms of being used as a tool to transform the activity. The development of the artefact transformed and expanded the activity in terms of P1 merely explaining the tutorial activity to P2 and P3 refining and developing a shared understanding of the tutorial activity (Figure 4).

The process of developing a reflective conceptual artefact (i.e. writing questions) also represented an inward informing of the participants (Gill & Bhattacherjee, 2007). This became evident later in the group activity when participants used a previously constructed conceptual artefact “writing questions” to refine the tutorial activity.

> P2 (3): Then asking people to pull out one theme at a time. To me the whole beauty is that you can dream up these thinking paths that make it easier for the participants to answer the question. Like I was going to talk to you about how to write.....questions
>
> P1 (4): Questions (speaking at the same time as P2)
>
> P2 (5): you need fat questions and not thin questions. Fat questions elicit response very easily so rather than, “list what you mean by knowledge” it is simply “what is knowledge”. List as many different ideas as you can....so it’s more of a action oriented statement...rather than list coming first, its what is knowledge......focus of it is what is knowledge....not discussion on...things like that....

P2 (3) while explaining the importance of thinking paths in the tutorial activity, re-introduced a previously constructed conceptual artefact “writing questions”. At this stage, P1 (4) knew what P2 was referring to. The previously co-created artefact (“writing questions”) served as a reference point for informing the participants. The artefact was created by P1 using reflection-in-action as a tool, and once created it was internalised by other participants. Thus when it was re-introduced in the discourse, the participants knew what it meant, its purpose and relevance. The use of previously constructed conceptual artefacts at a later stage in the activity represents the meaning making activity of participants which resulted from participants engaging with the planing activity. The process constitutes transformation of the artefact into the inner plane of participants. The understanding at an internal level is then externalized using common language developed by the group (in this case using the artefact “writing questions” to engage in discourse and inform other participants). This is illustrated by the interaction (3 & 4) that took place later in the activity where P1 (4) knew what P2 (3) is referring to (i.e. use of reflective conceptual artefacts for inward informing of participants).

Phase 2- Collaborative Reflective Discourse

Designing and planning of the tutorial activity required that each of the participants inform each other and negotiate perspectives. The next contradiction in the progression of the group activity occurred when P1 (6) explained the sub-process of identifying categories from the list of ideas generated as part of the student tutorial activity. The contradiction involved participants not having a shared understanding of how the categories will be developed in the tutorial activity. The contradiction also involved P2 and P3 objective of refining the tutorial activity. It is in the form of a question by P2 (7).

> P1 (6): Now what we do after each student has put in their ideas.....we try and develop some common themes in each of these categories.... (Asking question) - What is common within these ideas...and we try and put in themes....so....
>
> P2 (7): How does this theme thing works....just time out your process...can you put in more than one theme or not?

The object of this sub-activity evolves into developing a shared understanding and refining the particular process in the tutorial activity. This identified contradiction can be described as a contradiction between the second and third levels of informing. It shows the expansive and progressive (Aalst & Hill, 2006) nature of collaborative knowledge building activity whereby the object of the activity evolves and expands (Engeström, 2001), in this case into developing a shared understanding and the explicit description of sub-processes involved in the student tutorial activity.

The tool used by the group to solve the contradiction and develop shared understanding is collaborative reflective discourse whereby each participant is presenting their own personal perspectives, clarifying, questioning each other's understanding, presenting reasoning for their argument, developing a shared understanding, and finally building knowledge through discourse. This sub-activity is illustrated by the discourse following the question posed by P2 (7).

Collaborative reflective discourse involves firstly, making explicit personal viewpoint and perspective and presenting it to the group using language as a tool. P1 (6, 8) presents his perspective on how the group of students will develop and converge on categories using the theme tool from a list of ideas generated.

> P1 (8): Yes....lets say one of the themes coming out is knowing....action (Types in to show on Zing)......so that becomes one of the themes

P2 & P3 interpret and analyse the perspective based on their understanding and experiences. In trying to understand the perspective of P1, P2 (7, 9) posed a clarifying question and presented his initial analysis and feedback.

> P2 (9): But you only do one at a time? The second thing is.....Its always useful to get the participant's to do as much typing....when you use the themes box...you have to do the typing

At this stage, P1 (9) is not able to understand the usefulness of P2's idea and presents justification and rationale for following the process based on his experience.

The activity progresses by P2 (10) presenting his idea to the group. The perspective provided by P2 is in response to P1's initial explanation.

> P2 (10): Why not get one the one of the ....I don't use the themes box....so you need take this with a caveat....maybe we can work out how to operate...but, I always find that its rather than say "what are one of the themes"...it means we are going to ignore all the other things and try and pick out one. Whereas if we read through it... but before we read through it...we are told that we are going to pick what the common themes are...and you get each participant to record the theme in their box as you go through it.....so we read through it once and then we go back.....and we go though it again...so its about personal understanding...so you get one person (typing)....perhaps with some re-wording...next one is "justified belief"...how does that fit in (asks question)?.....what I' m doing now...is am going through and picking up everything and trying to put into groups...lets say P3 is "the knowing action....being able to do".
>
> So what I am doing is...I try and build up all the themes....now, if you want to capture them as themes all you have to do is run your mouse over it (shows)...and cut and paste it into the theme....or you can just get them to do this old trick and....F9 it.

The discourse here (10) illustrates P2 use of reflective thinking to articulate tacit knowledge. P2 is confronted with a challenging problematic situation and deals with it based on his personal belief and perspective. Then P2 brings experience into the thinking and problem domain, helping to reframe the thought. Finally, P2 integrates knowledge with the current problem and takes action in the form of a well defined process. In other words the participant is using reflection-in-action as a tool to deal with the problem and articulate knowledge. The process described above also confirms with the literature on the process and characteristics of reflective thinking (Rogers, 2001; Yukawa, 2006).

P2 (11) completes action on his idea and shows how the sub-process of developing themes can be achieved by the students. It is still not clear to P1 (12) how P2 idea works as compared to his personal viewpoint.

> P2 (11): now we have 4 themes…you can send them up after the xxxxxxxx…you can actually say……So you put in XXX-THEMES-XXX…I'll show you
>
> P1 (12): what I was thinking was….. I could open up the themes box & copy all these (shows on Zing)……they are highlighted…we can take it across & move it to the agenda
>
> P2: all right…we will do it that way
>
> P3 (13): You can do it the theme way...but if you highlight...theme no. 17 for example which was F9 up that would put it up to the thing anyway…and double clicking it will become the agenda
>
> P1 (14): it becomes the agenda
>
> P3 (15): yea…so you don't need to theme it to make it an agenda
>
> P1 (16): ok

It is at this stage through the intervention and action of P3 (13, 15) that P1 (14, 16) begins to understand why his idea of students developing categories using the theme tool would not be as effective as compared to the idea presented by P2 and P3. The discussion also shows the co-construction of what Yukawa (2006) refers to as representational artefacts. They are in the form of common terminology (themes, agenda, XXX-THEMES-XXX) and participants develop shared understanding by co-creating and interacting with these artefacts at the group level.

> P2 (17): the theme is good…but its another way of doing it dynamically without having to tell people …so we can f9 all of these n u can still bring them over anyway…see they are all there…
>
> P2 (18): now bring up your themes box
>
> P2 (19): can you highlight number 19 and copy it into…
>
> P2 (20): theme 19….can you highlight it…can you cut and paste…that's what I am asking

P2 (21): no (response to P1 way of developing themes) you got to go that way…no

P2 (22): go back a level and see if you can cut and paste in-situ

P1 (23): no… not in-situ

P3 (24): no…it didn't let…you have to do it that way

P1 (25): so if we are going to put them in Theme boxes…..it got to be done before its F9

P1 (26): that's why I was suggesting that…before we did the f9…I copy all the themes…no but I will have to copy it one by one

At this stage

P3 (27): hang on (Trying to work the theme thing, but didn't work)

P2 (28): that's easier than constructing them one by one (asking question)

P1 (29): I think this way is better (referring to P2 & P3 ideas)

In the discourse from statement 17 to 29, the participants try to make the sub-process of developing categories more efficient by exploring the possibility of using the theme tool. It is through taking action and exploring their beliefs and perspectives that leads to conceptual change and new understanding of the Zing tool and the process of tutorial activity.

The prominent contributions to the practice and literature of reflection and reflective practice have been those of Dewey, Boud and Schon (Kim & Lee, 2002; Yukawa, 2006). Important characteristics of reflective thinking include critical examination of beliefs and experiences, taking action, and affective changes to understanding2. In the discourse (20 to 31), the participants are collaboratively working together to develop a process for a tutorial activity. It is through attending to their perspectives, articulating and sharing knowledge with the group, evaluating them by taking action, and getting feedback that the group achieves shared understanding of the process and an

2 Affective change here refers to an increased capacity of participants to cope with divergent situations of activity and an ability of take action. For a more detailed discussion refer Rogers (2001).

effective change in conceptual understanding is brought about. This is illustrated in the response by P1 (26, 29) to P2 question (28).

Yukawa (2006, p206) in her study of action learning in groups identified "*three interactional characteristics of collaborative reflection: (1) sharing experience, information, and feelings; (2) achieving intersubjective understanding through collaborative meaning making; and (3) synergy between collaborative reflection and relationship building*".

Each of these characteristics is present in the discourse discussed here. P2 (10) and P3 (13) use their prior experiences for refining the tutorial activity, participants share experiences with the group, evaluate and reason perspectives, and develop shared understanding by taking action in the current activity. The participants were able to develop shared understanding by interacting with co-created artefacts and interpreting meaning using reflective thinking at the individual level and collaborative reflective discourse at the group level (17 to 29). The outcome of the individual reflective thinking activity (Figure 4), articulated knowledge artefacts (e.g. - writing questions), is used by all participants for developing a shared understanding.

The sub-activity of developing shared understanding and refining the tutorial activity is being mediated by participants using reflective thinking and developing reflective conceptual artefacts for reasoning and discussion. It also brings to the foreground the dynamic relationship between individual reflective activities and the social nature of collaborative reflective discourse with one helping the other. By individually engaging in reflective thinking, participants are able to articulate knowledge, create artefacts for discussion and interpret meaning. Collaborative reflective discourse involves explicitly seeking feedback through social interactions for examining multiple perspectives (Yukawa, 2006). The examination of multiple perspectives progresses through discourse and communicative actions such as reasoning, clarifying, and questioning. In other words, the outcome of individual reflective thinking activity is fed into the wider activity system at the group level for developing shared frames of references and shared understanding. The artefacts created by the group like "build up all the themes" (10) (different from Theme tool), "writing questions" (2), "fat and not thin questions" (5), "XXX-THEMES-XXX" (11), and "F9 it" (17, 26) only have meaning when they are understood in context of the activity. They were developed using reflective thinking as a tool at the individual level and collaborative reflective discourse was used as a tool to develop shared understanding at the group level.

Developing a shared understanding is a communicative process in context of an activity. It involves actions such as engaging in articulation of individual perspectives, discussions, questioning multiple perspectives, providing feedback, asking clarifying questions, and co-creating artefacts at the group level. Interaction through the co-created artefacts not only helped the group to develop a common terminology, but also mediated the process of developing a shared understanding. Yukawa (2006, p206) defines this process using the concept of collaborative reflective discourse. Collaborative reflective discourse is "*a collaborative critical thinking process involving cognitive and affective interactions between two or more individuals who explore their experiences in order to reach new intersubjective understanding*". P1 initial understanding of the sub-process of developing categories evolves based on the feedback, discussion and action by the group. Therefore the group comes to a shared understanding of developing categories, by not using the theme tool provided by the application, using collaborative reflective discourse as a tool (Figure 5).

Phase 3 – Collaborative Knowledge Building

The third phase involved the group of participants using their shared understanding to collaboratively build knowledge in the form of artefacts that are of importance and used in other activities (practice and process of student tutorial activity – culturally advanced activity aimed at the third level of informing environment of creating new designs). In this case it meant the participants having a shared vision of a tutorial activity which could be used in future to cover course material.

In terms of the process used by the participants and CKB the emphasis in is on developing shared objects of activity and collaborative advancement of conceptual artefacts (plans, products, theories) (Scardamalia & Bereiter, 1994). After developing a shared understanding about how to develop categories from a list of ideas (in the discourse it is referred to as themes and is different from theme tool provided by Zing), the participants discuss how students would develop summary statements explaining each category developed.

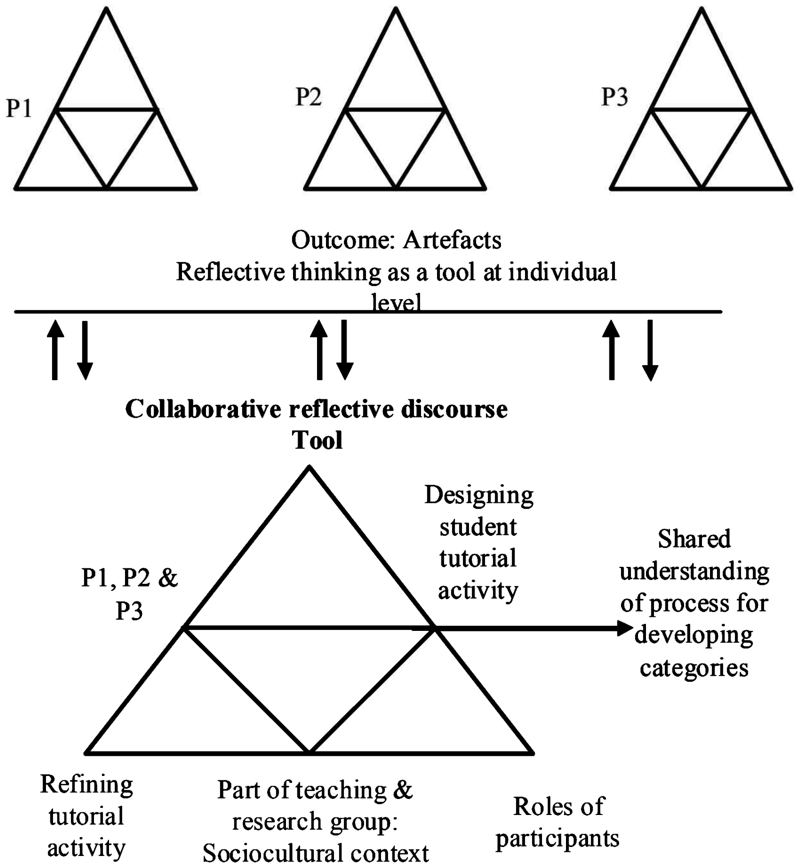

Figure 5: Collaborative reflective discourse as a tool

The activity progresses with P1 (30) explaining how students would develop summary statements explaining each of the categories (themes). The contradiction in shared meaning occurs with P3's questions (31) regarding the way the process should unfold.

> P1 (30): so after developing the themes…we click on one of the themes so that it becomes the agenda, then what they have to is…they have to discuss about it…what they understand about it…and I will also encourage…so say for e.g. I am saying "personal understanding is developing mental models"…I would like you to question it….as to what

> do you mean by mental models…all this is being done by putting in your ideas
>
> P3 (31): so do you want them to put in ideas…or do you want to discuss it
>
> P1 (32): I want them to put in ideas and at the same time if they have any doubt discuss it also. So say for example I put in "mental models" and f9 it and I would encourage if there is any other group member doesn't understand what I am saying or know they try and discuss it also…and at the end of it…when all the discussion has been done then using maybe theme or the way P2 does it you develop one common terminology
>
> P3 (33): you could ask them to put in what there ideas are and discuss each one….if you say does anyone does not understand you might not get anyone answering…as if anyone is going to say I don't understand that
>
> P2 (34): it needs to be a positive action rather than a negative action
>
> P1 (35): just coming back to what P3 was saying…discussing and listing ideas on one particular theme…so I should not encourage discussion and listing at same time…they list there ideas and then go onto the discussion
>
> P2 (36): you might need some discussion to get them thinking before they start typing…on the right hand side of the screen…Talk, Type. Read. Review is the protocol…so you talk about it…once ideas start flowing…you say lets capture those ideas on your keyboard…then they read it after they done the brainstorming…and then you review it and that's your discussion
>
> P3 (37): and you might have…like you don't know exactly what the themes are going to be from the first lot…but you know you are going to get themes out because that's what you are going to be asking about ….so are there questions you can pose to the group to talk about for that theme before they do the brainstorming…so you have generic questions you can ask about anything that comes up
>
> P1: (38) so that would stimulate the thinking

The discourse shows the development of a process for creating summary statements. It begins with P1 presenting his idea (30, 32), P3 questioning and refining it (31, 33), and moves to all three participants working together to create a thinking path (33, 35, 36, 37) for the students. This jointly constructed thinking path shows the co-construction of knowledge by the group that is not attributable to any single participant but to the group as a whole. The participants use co-created artefacts (put in ideas, generic questions, and thinking path) to engage in discussion leading to an effective conceptual change in understanding (35, 38). The outcome of the activity at this stage is in the form of a thinking path for students.

> P1 (39): after having listed ideas for themes, what I want is discussion…do you actually understand what these ideas mean…just as a group discuss what do u mean by " mental models "
>
> P3 (40): its maybe now that you have four layers…it maybe that …you read through them and then you go back up next theme and you go and do that
>
> P2 (41): this would be a good spot for the theme (referring to theme tool)……bring your theme up…I really actually love the participants to do the typing….it relieves me from ownership of it…gets them owning it…they can type while I am doing other things
>
> P3 (42): because you are running the process…the typing is content
>
> P2 (43): so how about you get us to develop a single summary statement of it….but don't F9 it n then you will cut and paste it into a theme…so that's what we will do…so take us through producing a single summary statement
>
> P1 (44): now what we are trying to achieve is we need to combine these 10 ideas into 1 or 2 sentences … (starts reading ideas on Zing)
>
> P2 (45): no…you said "mental models"…what do you want us to do with that…we going to sit here and listen to you or we engage some collaborative activity reflective activity…if we sit and listen to you…… we are not going to be very reflective
>
> P2 (46): "personal understanding and multiple realities" (reading from ideas on Zing)…does mental model belong in that…in other words we go and evaluate whether themes belong together or not
>
> P1 (47): so you pick out an idea…get out an idea in front of the group and ask them whether it fits in

> P2 (48): there is a collaborative assessment of that idea…so it's a collaborative reflective process… (Provides examples by working on 3 ideas)
>
> What you are doing is helping the group in collaborative reflective process…so 4 and 5 (referring to ideas on Zing) …are they sufficiently answered by what we already got there ,…if no then you get them to add more…but it's the group that's making the decision …that makes it a collaborative reflective process…not you
>
> This is what facilitator got to do…..prompt the group…reflect on this…does this fit…put it in for a reason…put things in to prompt the discussion …so in your lecturers…you put things in to bring up discussion (work on Zing to develop summary statement from ideas)
>
> P2 (49): so now can you cut and paste it into a theme (using theme tool)
>
> P1 (50): so that is one of the themes that has come out (referring to summary statement)

At this stage, P1 presents his idea on the way to develop summary statements (39). P2 and P3 build upon that idea (40, 41) and the emergent outcome (43) is in the form of a knowledge artefact and the value of this artefact only comes when it is placed in context of the activity. P2 further adds value to the knowledge artefact (practice and process of student tutorial activity) by providing feedback (45) and an affective conceptual change (e.g., see Tyson, Venville, Harrison, & Treagust, 1998) is shown by P1 (47). Statements 49 and 51 confirm that the group activity has resulted into an outcome, that is, in the form of practice and process for a student tutorial activity. The outcome is emergent in the discourse and not in individual statements by participants.

The discourse presented here shows the creation of a tutorial activity in the form of specific sub-processes based on a thinking path. Based on the principle of CHAT, every human activity is mediated through artefacts (cultural, social, language, conceptual, material). The artefacts in this case are "listed ideas for themes" (39), "combine these 10 ideas" (44), "collaborative assessment" (48), and "prompt the group" (48). It is through interacting with these artefacts that the participants are able to achieve the communal object. Each participant engaged in the activity uses reflective thinking as a tool at the individual level to develop or interpret the meaning of conceptual artefacts, collaborative reflective discourse as a tool at the group level for developing shared understanding of multiple perspectives and, co-create knowledge with the help of mediating artefacts.

The discourse shows the progressive nature of CKB as conceptualised by Aalst and Hill and (2006) and Bereiter (2002 as cited in Lipponen et al 2004). The participants have a communal object of designing a tutorial activity. Based on their individual expertise, participants are working towards reinvesting their learning and knowledge into a new problem situation for the advancement of community's knowledge through mutual understanding and discussion. The process is mediated through repair of contradictions between and among reflective conceptual artefacts using collaborative reflective discourse as a tool. The discourse also illustrates the mediating nature of knowledge building process (Lipponen et al., 2004). The group activity is concerned with the communal object of developing a tutorial activity and this shared object is what is driving the activity forward and transforming it. By identifying contradictions in shared meaning the participants are working towards developing a shared understanding. In other words, the contradictions are driving and transforming the activity.

The outcome at one level of activity system (see Figure 5) helps transform the activity (Figure 6) showing the expansive nature of CKB. The reflective conceptual artefacts move into the wider activity system for helping in the development of shared understanding. Shared understanding between the participants then expands the CKB activity system to help participants reach an outcome in the form of a practice or tutorial activity for students (Figure 6). The object within CKB activity system moved from a state of situationally given raw material (P1 presenting his tutorial design, (1)) to a collectively constructed shared meaning (P1 understanding of sub-process of developing categories scaffolded by P2 & P3, (29)) and to a collaboratively constructed shared object of the activity (combined ideas of P1, P2 and P3 resulting in refined tutorial activity, (40, 43, 47, 48)) (Engeström, 2001).

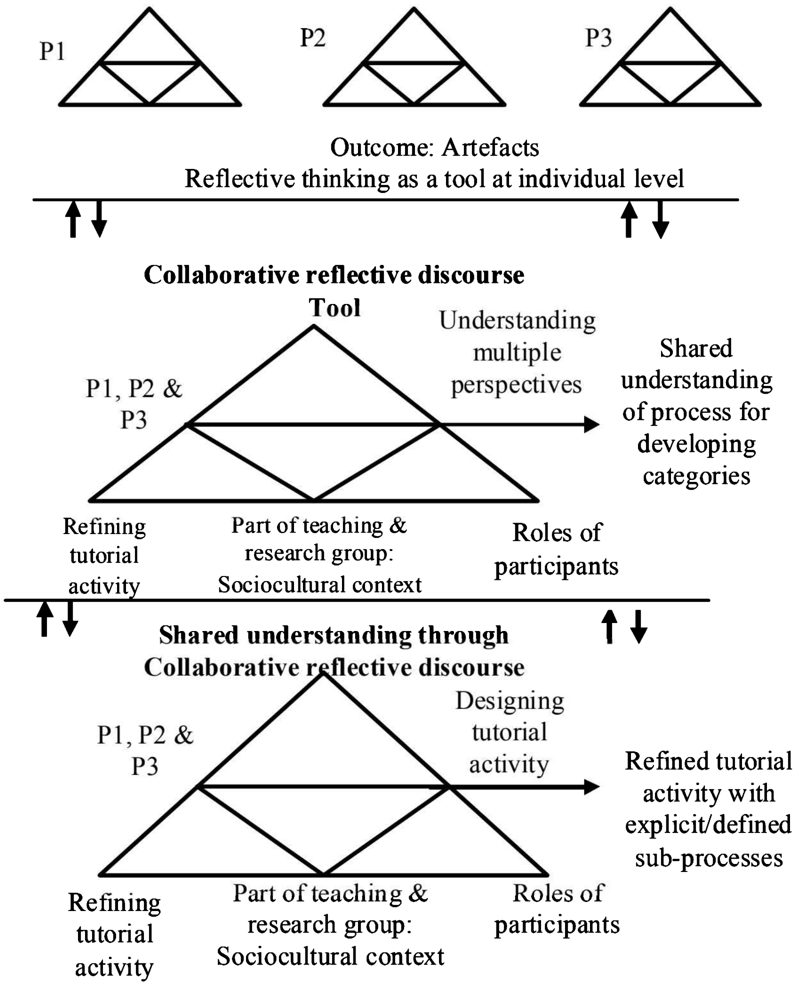

Figure 6: Expanded CKB activity system

CKB involves a set of complex processes and different interacting variables (group size, gender, social environment, nature of task, technology used, language, group composition, and relations) (Dillenbourg, 1999; Dillenbourg et al., 1996). To establish causal links between these variables or to represent the process diagrammatically is almost impossible. The model, however, can be a useful starting point for identifying the processes involved within CKB, understanding those processes, developing a sound theory, and possibly identifying processes for which technological scaffolds can be developed.

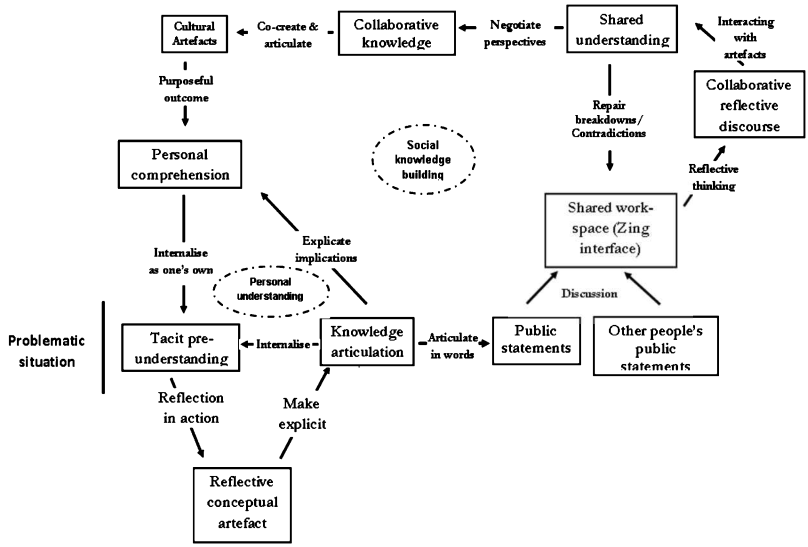

Figure 7: A model of CKB process (Adapted from Stahl, 2000)

The model (Figure 7) includes a cycle of personal understanding that is focusing at the individual level. Cycle 1 shows the use of reflective thinking as a tool at the individual level to develop reflective conceptual artefacts discussed in Phase 1. The reflective conceptual artefacts are used by participants while discussing different perspectives. Tacit pre-understanding represents the individuals use prior experiences and knowledge. When faced with a problematic situation, individual uses reflective thinking to articulate tacit knowledge in the form of conceptual artefacts and it is through interacting with these artefacts that individuals interpret meaning, are able to engage in discussions, develop a shared understanding and collaboratively build knowledge.

The social knowledge building cycle represents the CKB process at the group level. The shared work-space represents a common medium through which the participants are interacting and could be in the form a groupware application, message board, or even a face to face discussion. Once the participants have presented their personal perspectives and viewpoints on an issue, the group engages in discussion to develop shared understanding (cycle 2). Shared understanding is important in terms of making sure that each perspective is understood and participants are on some level of common ground. At this stage, collaborative reflective discourse is used as a tool for developing shared understanding. There is also a synergy between individual reflective thinking and collaborative reflective discourse with the former working at the individual level and latter at the group level. Even though cycles 1 and 2 are shown as separable, they are intertwined at various levels of abstraction in the CKB process. The cycles are separated in the model to highlight the modification to the original Stahl (2000) model of CKB. The development of the model is a starting point for developing a cohesive theory for CKB that would serve to provide a framework for designing informing environments to support the process. The next section summarises the contribution of the chapter in form of conclusions and also highlights future areas of investigation.

Conclusions

Social Constructivists maintain the emphasis on social interactions as a precondition for learning and knowledge building (Nyikos & Hashimoto, 1997). The case study presented here provides an activity theory analysis of group interactions. The constructs, language, and the diagrams provided by CHAT help in analysing the data and zoom in and out at the individual and group level to show the co-creation of knowledge in the form of an outcome. The ISF adds yet another dimension to the analysis by bringing our attention to the interrelated systems of informing, delivery and task completion system. Using ISF not only helped the researchers in analysing the CKB process, but also helped in informing the readers about the usefulness of ISF as a research tool. Focusing on the three systems, and specifically on the second and third level of informing environment helped us as researchers to provide a richer definition of the context, both across and within the various levels of informing. What is also particularly noteworthy in this context is the fact that while the levels were instrumental in forming the analysis, the basic structure of the ISF informing system model (i.e., sender, delivery system, and client) was largely irrelevant given the collaborative nature of the task being performed. This paradoxical combination of useful levels and irrelevant system model would seem to argue for the need to broaden our conception of informing systems to be more inclusive of peer-to-peer interactions.

The data analysis discussed above shows the creation of knowledge at the group level whereby the knowledge constructed is not attributable to any one participant but to the group. It brings to attention the possibility of a group zone of proximal development (ZPD) (Nyikos & Hashimoto, 1997) explaining the CKB process. ZPD is defined as "distance between the actual development level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers" (Vygotsky as cited in Nyikos & Hashimoto, 1997, p 507).

Each participant in the group has an individual ZPD. But through collaborative social interaction each individuals ZPD is extended and intersects at the group level. P2 and P3 based on their experience and expertise helped P1 to come to an understanding of how students can develop categories from a list of ideas. Alternatively, shared understanding and refining of the tutorial activity was only made possible by each participant presenting their perspective to the group, questioning and clarifying, engaging in discussion, and finally re-constructing meaning and the process. Therefore, collaborative reflective discourse is being used as a tool within this activity for helping individual and group ZPD, as part of the CKB process. Future studies need to focus on how to design technological scaffolds (i.e. delivery systems) which can support these group level processes of informing and knowledge building. Specific attention needs to be placed on analysing the relation between the three levels of informing environment abstraction taking place in a group context within specific domains and facilitated by informing systems.

One of the limitations of the study is the nature of the case study data used. However, the purpose of this paper is theory building and no generalization of the case study results is implied. Due to the fact that the case involved the authors in their teaching role, means that this paper has also provided a useful guide to reflective analysis of teaching activities (and of any collaborative exercise) using the activity as the unit of analysis.

The model of the CKB process presented here needs to be further corroborated with data to develop a cohesive theory and model of

CKB. Further studies in CKB need to focus on identifying and documenting the underlying processes involved in CKB. This study shows the efficacy of CHAT as an analytical tool, possible role of reflective thinking and collaborative reflective discourse in CKB, and the possibility of developing a theoretical framework for researching CKB based on informing science framework. The integrated model of CKB process can be used as starting point based on which informing environments and scaffolds for those environments can be designed. This chapter also opens up an interesting line of investigation – that is initiating a dialogue between ISF and CHAT based research, and how ISF concepts can be further enriched by using the descriptive power of CHAT and vice versa.

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Appendix: ZingThing

Zing groupware (ZingThing ®™ http://www.anyzing.com/) is a specialized groupware used to support group-work and collaboration. As a groupware, Zing upholds transparency and openness as a basis upon which participants communicate and interact through the groupware. The system provides opportunity for participants to engage with each other through typed conversations via keyboards (USB or wired). The system has inbuilt templates which can be used for wide variety of small group-work including collaborative learning, knowledge creation, strategy development, knowledge capture, risk assessment, SWOT analysis etc.

The physical setup of the system includes keyboards (input devices for each participant) connected to a single PC/laptop via wireless USB hub. The output screen or the shared work-space is similar for all participants and is shown in screen shots below.

Following Figure 8, each group participant has a 'playspace' (the small spaces at the lower part of the screen) to type their ideas. Participants press F9 to send their ideas to the 'teamspace' where the ideas are collected. The topic or the problem on which the group is working is shown in the 'focus box' and the current agenda in the 'agenda box'.

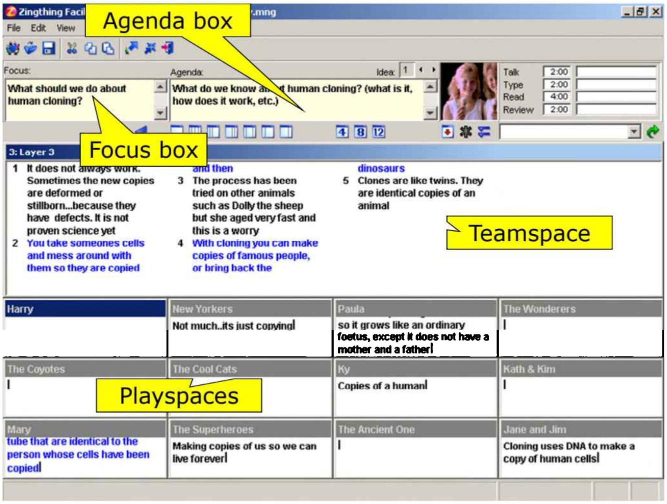

Figure 8: Zing groupware

Playspace 1 is by default for the facilitator of the electronic meeting. The facilitator introduces the topic which can be seen by all participants. The electronic meeting progresses with participants generating ideas through their individual playspaces and pressing F9 to send the ideas to the teamspace (Figure 9).

The Zing groupware provides for an interface for groups to work together, a thinking path for working on shared problems (talk, type, read, review protocol), a shared display where ideas can be reviewed, improved, analysed, and the system allows for the generation of a report which can be used later for analysis.

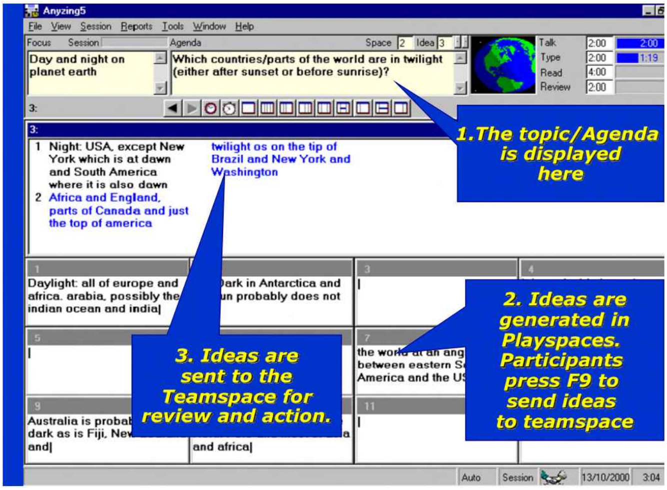

Figure 9: Idea generation and collection

The system allows for the evaluation of the generated ideas through various inbuilt interventions such as summarizing key ideas, integrating different ideas, picking up one idea and improving it, voting on ideas, prioritizing ideas etc. Figure 10 shows a screen shot of utilizing 'theme' intervention for summarizing ideas.

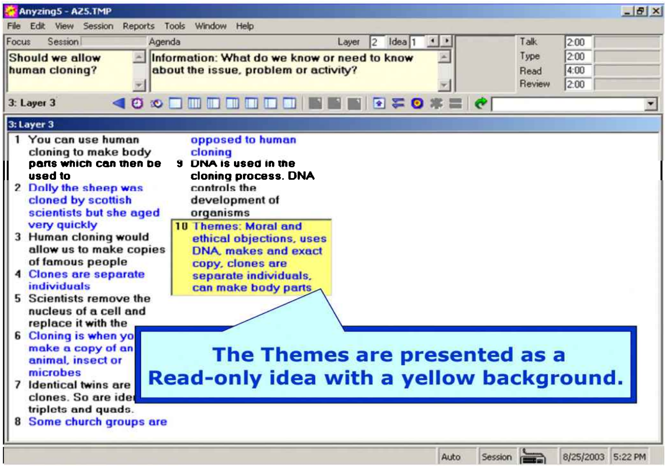

Figure 10: Idea summarization using Themes

Gill, T. G. & Cohen, E. (Eds.). (2009)
Foundations of Informing Science: 1999-2008
Santa Rosa, California: Informing Science Press (pp. 709- 737)

PART V: NEW DIRECTIONS FOR INFORMING SCIENCE RESEARCH

Chapter 21

The Poverty of Empiricism

Jens Mende

Abstract

Many researchers – and their advisors on research method – adopt a doctrine called *empiricism*, which claims that researchers may *only* use empirical methods. This restrictive doctrine impoverishes any academic discipline where it is dominant. The main reason is that a discipline only qualifies for the status of a science after it has progressed beyond empirical generalisations to explanatory theories; but although empirical methods are useful for discovering the former, they are inherently useless for creating the latter. So the empiricist doctrine retards scientific progress. Researchers should be aware of this danger, and research methodologists should attempt to counter it.

Keywords: Empiricism, Positivism, Research Methodology, research methods, empirical research, theoretical research

Introduction

There is a world of difference between the terms 'empirical' and 'empiricism'. The term '*empirical*' refers to a battery of very useful research methods. The term *'empiricism'* refers to a restrictive methodological doctrine which claims that researchers may *only* use empirical methods. The purpose of this paper is not to disparage empirical research methods, but to warn readers that the empiricist doctrine impoverishes any discipline where it is deeply entrenched (Gower, 1997, p10), and to suggest some avenues of counteraction.

The subsequent sections explain why the empiricist doctrine impoverishes research. The first section shows that researchers need knowledge of various kinds of research processes and knowledge products, and that this knowledge is distributed over three academic disciplines: *Philosophy of Science*, *History of Science* and *Research Methodology*. The next three sections examine the origin and current status of the empiricist doctrine in the Philosophy of Science, and the debilitating effect of empiricism on research process and product knowledge in the History of Science and in Research Methodology. The last section calls for counter-action in the form of meta-research aimed at identifying non-empirical research processes and knowledge products that could be mentioned in those three disciplines – especially in Research Methodology.

As the argument in those sections is lengthy, no space is left over for detailed analysis of the impact of the empiricist doctrine on the Information Systems discipline, nor on any of the other disciplines under the umbrella of Informing Science. Readers are invited to judge by themselves, from their personal experience, whether those disciplines are dominated by the empiricist doctrine, and whether that doctrine has impoverished them.

Methodological Knowledge

Research is a process of producing new knowledge. So it is a *productive* process similar to the productive processes of manufacturing cars, computers, software, etc. Some useful insights emerge by analysing the other productive processes and then comparing them with the research process.

All productive processes require productive knowledge. For example:

- in order to produce cars, people need knowledge of car production;
- in order to produce computers, they need knowledge of computer production;
- in order to produce software, they need knowledge of software production.

Productive knowledge consists of *process* knowledge as well as *product* knowledge (see Mende, 2000 for more detail). When manufacturers establish a new factory, they have to decide what the factory is to produce, and how the factory will produce it. So they need to know what kinds of manufactured products are needed, and what kinds of processes can be used to produce them. For example, when Henry Ford decided to produce motor cars, he had to know that people need cars, and that cars can be produced on a production line.

Similarly, when researchers embark on a research project, they have to decide what knowledge product to produce and how to produce it. So they too need to know what kinds of knowledge products are required and what kinds of research processes can be used (Kantorovich, 1993, p11; Singleton, Straits & Straits, 1993, p18). For example, when Ohm embarked on his famous research project to find the empirical law of electric current variation with voltage, he had to be aware that people need empirical laws, and that empirical laws can be produced by means of inductive research processes. Similarly, when Darwin embarked on his famous research project on the theory of evolution, he had to be aware that people need theories, and that theories can be established by means of deductive research processes.

Therefore, by analogy with manufacturing management, researchers need knowledge of different types of research processes and knowledge products. Since this is knowledge about knowledge, it may be called 'meta-knowledge'. For convenience of access, all our meta-knowledge should be concentrated in a single academic discipline. But that is not so. Instead, our meta-knowledge is scattered across three different disciplines, namely History of Science, Philosophy of Science and Research Methodology.

History of Science is an old-established discipline, which began with the ancient Greeks (Lloyd, 1973). Today, it describes many of the knowledge products that were discovered by real-life researchers, and also some of the research processes that those researchers actually used.

Philosophy of Science is another old-established discipline, which also began with the ancient Greeks. Today, it mainly analyses the validity of existing knowledge products, but occasionally considers the research processes too. Unfortunately, many publications in Philosophy of Science make scant reference to History of Science, and most of them ignore Research Methodology altogether.

Research Methodology is an emerging new discipline that aims to unify many of the methodological principles found in the various sciences and proto-sciences. During the latter half of the 20th century, specialised methodological branches have emerged in many of those disciplines to focus on issues of method. For example, in the natural sciences there are textbooks on experimental techniques of physics and chemistry, and on microscope techniques in biology and geology (Furniss, Hannaford, Smith, & Tatchell, 1989; Heinrich, 1965; Sanderson, 1994). In the social proto-sciences there are textbooks on experimental psychology, sociological method, anthropological research, educational research and business research (Cassell & Symon, 1994; Christensen, 1980; Cole, 1980; Foskett, 1965; Pelto & Pelto, 1978; Zikmund, 2003). Yet certain methods are common to many of these disciplines.

> "The research procedures of most academic disciplines follow the dictates of the scientific method … In many instances, only the tools of research are different. The biologist gathers data by way of the microscope, the sociologist does likewise through a questionnaire. From there on the basic procedure of each is the same: to process the data, interpret them, and reach a conclusion based on factual evidence." (Leedy, 1989, p. vii).

The new discipline of Research Methodology identifies and explains these common research procedures. Unfortunately, most publications in Research Metholology make scant reference to Philosophy of Science and History of Science.

The three disciplines are subject to the force of *fashion* (Lovelock, 1995, p. 204; Nagel, 1961, p. 115; Sperber, 1990). This force arises in any social group, including a community of scholars. A scholar in an academic discipline is subject to research fashions in the same way as anyone else is subject to clothing fashions, motorcar fashions, food fashions, etc. The next three sections focus on the empiricist fashion. It originated in the Philosophy of Science, where it is now dismissed with contempt; but has spread to History of Science, where it is still mildly influential, and to Research Methodology, where it remains dangerously dominant.

Philosophy of Science

The precursor of empiricism was a philosophical doctrine called *positivism*. This was a doctrine of neglect. It called for neglect of a particular class of knowledge *products*, namely *theories*, and especially those theories that involve un-observable first causes (Oldroyd, 1986, p. 169). Positivism originated in the 18th century, when Berkeley denied the reality of theoretical objects such as the Newtonian forces of mechanics (Losee, 1993, p. 168). Positivism was subsequently disseminated by two influential 19th century philosopher-scientists: the sociologist Comte, who asserted that 'science must study only the laws of phenomena', and the physicist Mach, who attempted to purge all theoretical terms from Mechanics (Losee, 1993, p. 170; Whewell, 1860, p. 183). Positivism was disseminated even more widely in the early 20th century, by a group of philosophers called the Vienna Circle, who regarded theoretical objects as meaningless, and a theory as a mere computational device for describing and predicting phenomena (Harre, 1960, p. 46; Hollis, 1994, p. 42).

Empiricism (or *inductivism*) is the logical consequence of positivism for research *processes*. In the same way as positivism dismisses theory, the doctrine of empiricism dismisses deductive theoretical methods, and demands that researchers should restrict themselves to inductive empirical methods.

> "induction … is the method proposed by crude empiricism to distinguish scientific inquiry from non-scientific speculation" (Doyal & Harris, 1986, pp. 2-3).

The remainder of this section demonstrates that the positivist and empiricist doctrines are dangerously restrictive. These doctrines fail first to an inductive empirical argument, and then to a deductive explanatory argument.

The inductive argument is based on evidence from the History of Science, namely the many instances where empirical methods produced significantly less useful knowledge products than theoretical methods.

- Empirical methods merely enabled Galileo to discover the law of falling, whereas theoretical methods enabled Newton to discover the theory of Mechanics.

- Empirical methods merely enabled Ohm to discover the law of electrical resistance, whereas theoretical methods enabled Maxwell to discover the theory of electrodynamics.

- Empirical methods merely enabled Proust to discover the law of constant proportions in chemical reactions, whereas theoretical methods enabled Dalton to discover the atomic theory of chemistry.

- Empirical methods merely enabled Darwin to discover new biological species, whereas theoretical methods enabled him to discover the theory of biological evolution.
- etc., etc.

So, empirical methods were often less useful than theoretical methods. Now if today's researchers were trapped into empiricism, they would be restricted to empirical methods, and would be unable to produce the more useful theories. Therefore empiricism would impoverish research.

The deductive argument against the positivist empiricist doctrines is based on two propositions of the modern Philosophy of Science:

1. A true science has an explanatory theory that is organised as a deductive system.
2. Empirical methods are inappropriate for creating explanatory theories.

Proposition 1 means that an academic discipline does not qualify for the status of a science until it has progressed beyond empirical generalizations to explanatory theories. For example, the branches of Physics and Astronomy now called Dynamics and Celestial Mechanics were labelled 'natural philosophy' at the time Galileo formulated his empirical laws of motion and Kepler formulated his empirical laws of planetary orbits. They only achieved the status of sciences after Newton devised a deductive theory to explain Galileo's laws and Kepler's laws (Toulmin, 1953, p. 50). The first proposition is supported by the quotes in Table 1.

Proposition 2, which asserts that empirical methods are inappropriate for creating explanatory theories, follows from the fact that empirical research involves *inductive* reasoning, whereas theoretical research involves *deductive* reasoning. Empirical methods induce generalisations from facts. Theoretical methods then explain the empirical generalisations by generating *deductive* arguments to the generalizations from first causes, which are usually un-observable. So inductive methods are useless for devising deductive explanatory theories.

This proposition is easy to confirm from cases in the History of Science. For instance, Newton made no observations or experiments, and analysed no data in devising the theory of Mechanics; neither did Dalton in devising the atomic theory of Chemistry, nor Darwin in

Table 1. The need for explanatory theories and deductive systems

Source	Quote
Copi, 1979	"No mere list or catalog of truths is ever said to constitute a system of knowledge or a science. We have scientific knowledge only when the propositions setting forth what we know are organized in a systematic way, to display their inter-relations … one important relationship among the propositions of a science is deducibility. Propositions that embody knowledge about a subject become a science of that subject when they are arranged or ordered by displaying some of them as conclusions deduced from others" (p157).
Campbell, N. R., 1920	"the more purely phenomenal a proposition is and the less the element of theory associated with it, the less is its certainty … For why do we call some laws 'empirical' and associate with that term a slight element of distrust? Because such laws are not explained by any theory" (p153).
Harre, 1960	"it has been one of the fundamental aims of science to reach deductive systems of knowledge" (p39).
Harre & Secord, 1972	"The experimental work of Hooke and Boyle by which they established the empirical patterns in the behaviour of confined samples of gas that we express as PV = K … was proto-scientific. We do not have real science until we know why P varies inversely as V, knowledge which became available only after the molecular theory of gases was formulated to provide us with an idea of the causal mechanism by which this pattern was produced … Science proper starts when the question 'Why?' is put and theory develops to answer it." (p130-1).
Kantorovich, 1993	"theory is one of the distinguishing characteristics of modern science" (p16).
Klee, 1997	"explanation [is] the main business of science" (p4).
Mason & Bramble, 1978	"the purpose of science is to develop theory, which can be defined as a set of formulations designed to explain and predict phenomena" (p3).
Phillips, 1985	"One goal of the scientific method is explanation: a theory as to the causes and/or effects surrounding a given phenomenon" (p10).
McBurney, 1994	"The ultimate goal of a science is the development of a theory to explain the lawful relationships that exist in a particular field" (p40).

devising the biological theory of evolution, nor Einstein in devising the relativity theory.

Table 2 provides further support from other authors.

The positivist and empiricist doctrines now fail to a simple *reductio ad absurdum.*

- Science is characterised by the existence of deductive explanatory theory.
- Yet inductive empirical methods are inappropriate for creating deductive explanatory theory.

Table 2. Inadequacy of empirical methods for creating explanatory theories

Source	Quote
Timasheff, 1957	"Theory cannot be derived from observation and generalizations merely by means of rigorous induction".
Nagel, 1961	"a theory cannot be an empirical generalization from observational data" (p85).
Koestler, 1969	"on Einstein's own testimony the Michelson-Morley experiment 'had no role in the foundation of the theory' …. [It] was laid on theoretical, indeed speculative, considerations" (p243-4).
Popper, 1978	"But what about the method by which we obtain our theories or hypotheses? … I do not believe that we ever make inductive generalizations in the sense that we start with observations and try to derive our theories from them" (p19).
Hughes, 1990	"All the 'facts' Darwin used as evidence for his theory of evolution were known before he used them ... What Darwin contributed was a profoundly radical way of rearranging these materials" (p38).
Kantorovich, 1993	"Inductive inference can generate empirical generalizations, but not explanatory theories … Newton's theory of universal gravitation cannot be inductively inferred from the data on planetary motion and even not from Kepler's laws …inductive generalization cannot lead from the data on gas behaviour, or from the empirical gas laws, to the kinetic theory of gases" (p66).

- So inductive empirical methods are unlikely to produce a science.
- The empiricist doctrine restricts researchers to inductive empirical methods.
- So it impoverishes research by inhibiting progression to scientific status.
- Yet the aim of this doctrine is to ensure scientific status.
- Therefore empiricism is absurd.

So empiricism is untenable in the Philosophy of Science. Indeed, some philosophers have rejected the absurd empiricist doctrine in the past, and many others reject it today – see table 3.

Nevertheless, empiricism still influences the other two disciplines that are concerned with research method.

Table 3. Criticisms of Empiricism

Source	Quote
Bacon, 1620	"The Empiric school produces dogmas of a more deformed and monstrous nature than the Sophistic or theoretic school (p29).
Bunge, 1967	"Empirical induction, i.e. generalization of observed cases, has been grossly overestimated by philosophers who have concentrated on the early (pretheoretical) stages of research" (p244).
	"The [extent] of theoretical work measures then the degree of advancement of a science … This is why psychology and sociology, despite their huge store of empirical data and low-level generalizations, are regarded as being still in an underdeveloped stage: because they do not abound with theories wide and deep enough to account for the available empirical material. Yet in these as well as in other underdeveloped departments of inquiry theorizing is frequently regarded as a luxury and data gathering – i.e. description – as the only decent occupation, to the point that theory (speculation) is opposed to research (data hunting). This paleoscientific attitude, encouraged by a primitive kind of empiricist philosophy, is largely responsible for the backwardness of the sciences of man" (p382).
Harre & Secord, 1972	"A philosopher is often put in mind of the analogy to alchemy, where an enormous amount of empirical and experimental work was done, some of which was later incorporated into real chemistry, but most of which was vitiated because of an inadequate conceptual basis" (p3).
Gould, 1979	"Great scientists … are distinguished more by their powers of hunch and synthesis than by their skill in experiment and observation".
Wartofsky, 1979	"early positivism, and its modifications in … empiricism have failed" (p27)
Chalmers, 1982	"I regard the naïve inductivist account of science to be very wrong and dangerously misleading" (p11).
Doyal & Harris, 1986	"Traditional ideas about scientific method have been the target of much recent criticism. This has been directed particularly against empiricism … The critics of empiricism claim that it never was and never could be the method of science and that the conscious or even unconscious adherence to its principles could retard progressive scientific discovery" (p1).
Hull, 1988	"I had become increasingly dissatisfied through the years with the logical empiricist analysis of science that had been so popular for over a generation (xi).
Laudan, 1996	"the positivists had mistaken ideas both about the agenda for philosophy and about the solutions to certain prominent problems (p3).
Azevedo, 1997	"Current adherents to positivism and empiricism are considered ignorant and behind the times" (p258).

History of Science

Historians of Science are subject to the force of fashion – particularly by fashions in the Philosophy of Science.

> "The historiography of science, more than the history of other aspects of human thought, is peculiarly subject to philosophic fashion" (Hesse, 1980, p. 3).

Many older historians have been influenced by the old empiricist philosophy (Hesse, 1980, p. 4; Hollis, 1994, p. 42). So when they decide which processes and products to study, they are likely to over-emphasise empirical processes and products, and neglect theoretical processes and products (Hesse, 1980. p. 5). Therefore, *historians may have missed potentially useful research products and processes.*

Research Methodology

The authors of Research Metholology textbooks are also subject to the force of fashion. They have been influenced by two fashions, namely scientism and empiricism.

Scientism was a pervasive research fashion until a few decades ago. According to this fashion, all scientists ought to emulate the 'empirical-analytical' method, which was supposedly used by many natural scientists, particularly physicists.

> "The empirical-analytical method is the only valid approach to improve human knowledge. What cannot be investigated by it, cannot be investigated scientifically at all and therefore must be banned from the domain of science as unresearchable and consequently as unpublishable, unfundable and almost as unspeakable" (Klein & Lyttinen, 1985).

Empiricism is the pervasive research fashion today … see Table 4.

The empiricist doctrine is reflected in most of the textbooks of Research Methodology that were published during the past four decades. Their authors insist that research should invariably, or normally, involve *data collection* (by observation, experiment, document study, etc.), and *data analysis* (by inductive statistical and/or interpretive methods).

The authors rarely state these norms explicitly, but rather let their readers infer them implicitly. They do that in three ways.

Table 4. The popularity of positivist empiricism

Source	Quote
Von Bertalanffy, 1968	"Only collection of data and experiments were considered as being scientific in biology (and psychology); *theory* was equated with *speculation* or *philosophy*, forgetting that a mere accumulation of data, although steadily piling up, does not make a *science*" (p100).
Harre & Secord, 1972	"most psychologists have adopted a logical positivist metaphysics and the methodology that goes with it" (p32).
Easthope, 1974	"the tool – the scientific method – began to determine sociological aims" (p139).
Doyal & Harris, 1986	"Empiricism in its crudest form is probably the epistemology which is most generally accepted by people without philosophical training" (p2).
Miller, R. W. 1987	"At least as a working hypothesis, positivism is the most common philosophical outlook on science" (p4).
Hughes, 1990	"I refer to positivism as the orthodoxy because, in some of its versions, it is the philosophical epistemology that currently holds intellectual sway within the domain of the social sciences" (p16).
Azevedo, 1997	"For the greater part of this century [positivism] was the dominant philosophy of science and it has been influential in sociology since the discipline was first developed … while positivism is no longer dominant in the philosophy of science, it still dominates sociology, at least in the United States" (p14+41).
Gower, 1997	"The traditional accounts of scientific method, then, offer a logic of science which is biased … heavily in favour of an empiricist epistemology and ontology" (p259)

First, some authors simply *define* 'research' as a process of data collection and data analysis (e.g. Bailey, 1987, p. 11; Creswell, 1994, p. xvii; Erlandson, Harris, Skipper, & Allen, 1993, p. xvii; Leedy, 1989, p. 9; Miller, D. C., 1970, p. v; Neale & Liebert, 1986, p. 7; Riley, 1963, p. xiv; Tuckman, 1978, p. 12-14; Williamson, Karp, Dalphin & Gray, 1982, p. 4).

Second, other authors define 'the scientific method' as a process of data collection and data analysis (e.g. Bynner & Stribley, 1978, p. 4-8; Heiman, 1995, pp. 9, 19; Kerlinger, 1986, pp. 10-13; Labovitz & Hagedorn, 1976, p. 23; Leedy, 1989, p. 80; Lehmann & Mehrens, 1979, p. 3; Mason & Bramble, 1978, p. 26; McMillan & Schumacher, 1997, p. 9; Neuman, 1994, p. 8-11; Rummel, 1964, p. 11-15; Williamson et al., 1982, pp. 6-8).

Third, others define the 'hypothetico-deductive method' as hypothesis deduction from theory followed by data collection and analysis, and recommend this method as the model of research in any science (e.g. Bailey, 1987, p. 39; McNeill, 1985, p. 42; Sekaran, 1992, p. 16, TerreBlanche & Durrheim, 1999, p. 4).

So the textbooks of Research Metholology either *implicitly* adopt the empiricist doctrine, by excluding all research methods other than the empirical methods, or *explicitly* adopt the empiricist doctrine, by suggesting that empiricism is necessary for an academic discipline to achieve scientific status. Examples are shown in Table 5.

Table 5. Empiricism in textbooks of Research Methods

Authors	Quotes
Turney & Robb, 1971	"in [using] the scientific method .. the investigator … collects, organizes, tabulates, and analyses his data" (p4).
Tuckman, 1978	"Characteristics of the research process. Research is empirical" (p10-11).
Williamson, et al. 1982	"Systematic research in any field of inquiry involves two basic operations… data collection [and] data analysis" (p4).
Phillips, 1985	"we must proceed to collect data [and] analyze data" (xi)
Kerlinger, 1986	"scientific investigation is empirical" (p11).
Bailey, 1987	"Each research project entails gathering data, analyzing data and interpreting data" (p11).
Erlandson et al., 1993	"we hope they find in this book a way of collecting, analyzing and reporting data" (xvii).
Singleton et al., 1993	"the foremost characteristic of scientific inquiry is that it is based on empiricism" (p30).
McBurney, 1994	"Empiricism is an essential characteristic of science" (p7).
Cooper & Emory, 1995	"This book is concerned with empiricism" (p23).
McMillan & Schumacher, 1997	"Research is characterized by a strong empirical attitude and approach …" (p12).

There are at least three reasons why positivism and empiricism are popular among researchers and their methodological advisors. One reason is that, "Today's science teaching reflects yesterday's philosophy of science" (Kantorovich, 1993, p. 255).

Another reason is that many research advisors know a great deal about confirming and falsifying theories, but know next to nothing about creating them (Phillips, 1985, p. 8). Furthermore, they seem to be unaware that their (physicist) role-models used *not only* inductive empirical methods of confirmation *but also* used deductive methods of discovery (Chalmers, 1982, pp. xv-xvi). So when authors write textbooks of Research Methodology, they would have no option but to emphasise the well-known empirical methods, and neglect the little-known theoretical methods. Similarly, some authors may neglect theoretical methods because they are unaware of the deductive-explanatory role of theory (e.g. Breakwell, Hammond & Fife-Shaw, 1995, p. 5; Bynner & Stribley, 1978, pp. 4-9; Erlandson et al. 1993, p. 16, 50; Kerlinger, 1986, p. 9; Labovitz & Hagedorn, 1976, pp. 14-18; Leedy, 1989, p. 7; Mason & Bramble, 1978, p. 53; McNeill, 1985, p. 176; Mouton & Marais, 1990, p. 143; McMillan & Schumacher, 1997, p. 8; Neuman, 1994, pp. 41-43; Sekaran, 1992, p. 20, Singleton et al., 1993, p. 23; Riley, 1963, p. 9; Terre Blanche & Durrheim, 1999, p. 404).

A third reason is that some researchers and their advisors have made *a virtue of necessity*. They confine themselves to empirical methods because theoretical methods have not yet been seen to succeed.

> "A great many parts of physics are tied together with a strong interconnecting network of fundamental physical theory from which all other parts can be derived, so-called first principles. On the other hand we have fields … where empiricism is the order of the day simply because there is no generally valid group of first principles from which to operate." (Siever, 1970, p. 23-4).
>
> "In the early periods of developing a discipline from an applied field, initial efforts are usually directed more toward establishing empirical facts. Later, facts from separate studies can be synthesized and ultimately integrated into theories." (McMillan & Schumacher, 1997, p. 22).

This explains why some authors, even though they are aware of deductive explanatory theory, nevertheless restrict their textbooks mainly or exclusively to empirical methods (e.g. Babbie,1989, p. 46; Heiman, 1995, p. 17; McBurney, 1994, p. 42; Miller, D. C., 1970, p. 9; Phillips, 1985, p. 11; Rosnow & Rosenthal, 1996, p. 39; Singleton et al., 1993, p. 23; Williamson et al., 1982, p. 23).

Nevertheless, whatever the reason for conforming to the positivist-empiricist doctrine, that doctrine is absurd, and can therefore be harmful. It is likely to be harmful in at least two ways. First, if researchers are restricted to inductive empirical methods, they would be unable to produce deductive explanatory theories: so positivist empiricism would paralyse theoretical research. Second, positivist empiricism is likely to affect the methodological selection mechanism. In the many academic disciplines that are dominated by positivist empiricism, researchers will tend to reject any Research Methology textbook that fails to conform to the dominant fashion. So the authors will be motivated to conform too. The conformist textbooks would then reinforce the dominant fashion among research students.

Several other authors have expressed additional concerns, shown in table 6.

Research cultism. A research cult can form if a research fashion becomes self-perpetuating. Klein & Lyttinen (1985) have explained how this can happen. Suppose a specific set of research processes and knowledge products has become fashionable in a particular discipline. Then research supervisors who adopt that fashion will insist that their

Table 6. Objections to positivism and empiricism

Source	Quote
Harre & Secord, 1972	"The need for … a reformed methodology we feel to be pressing, and to be evident from the increasing dissatisfaction with the state of social psychology. The underlying reason for this state we believe to be a continued adherence to a positivist methodology, long after the theoretical justification for it, in naïve behaviourism, has been repudiated" (p1). "what many psychologists and some other behavioural scientists are doing is overemphasizing empiricism at the expense of conceptualization, or fact at the expense of ideas. They are acting as if observation and experiment by themselves can create a science. This misplaced emphasis stems from an approach to science via logical positivism" (p36).
Chalmers, 1982	"Many areas of study are described as sciences by their supporters, presumably in an effort to imply that the methods used are as firmly based and as potentially fruitful as in a traditional science such as physics. … Self-avowed 'scientists' in such fields will often see themselves as following the empirical methods of physics, which for them means the collection of 'facts' by means of careful observation and experiment … failing to realize that the method they endeavour to follow is not only necessarily barren and unfruitful but also is not the method to which the success of physics is to be attributed." (xv-xvi).
Azevedo, 1997	"The desire of the abstracted empiricists to be scientific and their belief that positivism provided *the* scientific method led them to follow its prescriptions in a way never seen in the natural sciences, even in physics, of which positivism was an attempted, if unsuccessful model. They allowed 'the scientific method' to determine the sort of problems they took up and the ways in which they were formulated" (p15).

students use the fashionable research processes to produce the fashionable knowledge products. When these students in turn become supervisors, they too will insist that their students use the fashionable processes to produce the fashionable products. And so on.

Cults are likely to form around positivist-empiricism:

> "All those who do not abide by the precepts of empiricism are thus threatened with excommunication from the bosom of science" (Doyal & Harris, 1986, p1).

Cults are particularly likely to form in academic disciplines that have not yet secured scientific status, which include the social 'sciences' and most other disciplines except the natural sciences.

> "One of the livelier academic debates of recent years has concerned the scientific status of those disciplines gathered under the heading social sciences … Academicians have disagreed about calling these disciplines sciences" (Babbie,1989 p30).

In these disciplines, an additional mechanism of cult formation is present. The leaders of these disciplines aspire to scientific status, but have not studied Philosophy of Science. So they are easily trapped by the positivist or empiricist doctrines. When that happens, it affects hiring and promotions, the funding of research projects, and the publication of research papers. Accordingly, subordinate researchers are obliged either to accept those doctrines too, or else give up a research career. So a vicious circle forms, and those doctrines can dominate the entire discipline within a few decades. For example,

- during the 1930's and 40's, a positivist cult probably formed in American Psychology. It was called behaviourism. Watson, Skinner, and their followers restricted psychological researchers to a program of naïve experimentalism, and repressed any attempt to use intervening variables in explaining human cognition (Cziko, 1995, p. 93; Gardner, 1985, p. 109; Harre & Secord, 1972, p. 136; Hothersall, 1990, p. 405).

- during the 1980's, an empiricist cult may have formed in Information Systems. American PhD supervisors restricted graduate students to a range of methods that were unable to answer questions of systems effectiveness (Klein & Lyttinen, 1985; Nissen, 1985). And funding committees imposed the same restrictions on researchers (Fitzgerald, Hirshheim, Mumford & Wood-Harper, 1985).

Positivist-empiricist cultism would intensify the harmful effects identified earlier. These cults would be dangerously restrictive, confining researchers to a narrow range of processes and products (Bauer, 1992, p. 75; Harre, 1981; Lovelock, 1995, p. xvii; Whitley, 1984, p. 146). In particular, they would paralyse theoretical research, and that would – ironically – prevent an academic discipline from achieving scientific status. The failure to achieve scientific status may then step up the vicious circle. Academic leaders would attribute the failure to insufficiency of empirical research, and increase their efforts to eliminate non-empirical research. As a result, empiricist cultism can retard progress for decades – as happened in Psychology sixty years ago, and as may be happening in Information Systems today.

Positivist and empiricist cultism are also likely to affect the methodological selection mechanism. For instance, if an academic discipline is dominated by an empiricist cult, then researchers would be strongly discouraged from doing any non-empirical work, and would avoid buying any Research Metholology books that do not conform to the ruling empiricist doctrine. So when methodologists write metholology textbooks, or teach metholology courses, they would be totally rejected unless they conform to the empiricist mould. Therefore, if many academic disciplines are dominated by empiricist cults, the demand for non-empiricist Research Metholology books would shrink to extinction, and publishers would avoid such books. This would account for the flood of empiricist textbooks of Research Metholology that is reaching the bookshops today.

In summary, then, the emerging discipline of Research Methodology is facing some very serious problems. Methodologists may be inhibited by research fashions. They are probably inhibited by the empiricist fashion (or even cult), which is likely to paralyse theoretical research. As a result, methodologists have probably missed many useful research processes and knowledge products.

Content analysis. This suspicion was confirmed by analysing a sample of Research Metholology textbooks whose authors appear to have minimum bias towards positivist empiricism. Table 7 identifies the actual research processes mentioned in these textbooks, and lists them in empirical and non-empirical columns.

Table 7 has two implications. First, the non-empirical column has relatively few entries. So even though the textbooks were selected for minimum bias, each one actually has a very strong positivist/empiricist bias. Generalising from the sample, one would therefore expect that

> *most textbooks of Research Metholology are biased towards positivist empiricism.*

Second, few such books provide any coverage of several important research processes that have been mentioned by philosophers and historians of science. For instance:

- *Serendipity*, to find a proposition about one type of object while studying another type of object (Bauer, 1992, pp. 87, 111, 118, 121; Boden, 1990. pp. 15, 49, 218; Bundy, 1997, p. 21; Campbell, D. T., 1974, pp. 427, 435; Chalmers, 1982, p. 34; Csikszentmihalyi, 1996, p. 196; Harre, 1985, p. 172; Kantorovich, 1993, pp. 3, 7, 101, 148-171, 154, 166, 180, 223; Miller, A. I., 1996, pp. 95, 374, 375; Popper, 1979, p. 108; Singleton et al., 1993, p. 29; Whewell, 1860, pp. 119-121; Wuketits, 1990, p. 164; Ziman, 1978, pp. 131, 139, 148).
- *Conjecture*, to guess a potential solution to a problem (Bauer, 1992, p. 45+111; Bundy, 1997, p. 22; Campbell, D. T. 1974, p. 427;Campbell, N. R., 1920, p. 225; Chalmers, 1982, p. 44; Einstein & Infeld, 1938, p. 47; Gower, 1997, pp. 43, 118, 125; Harre, 1960, p. 175, 1970, pp. 39, 42, 46, 52; 1985, pp. 171, 180; Harre & Secord, 1972, pp. 73, 76, 180; Hesse, 1974, pp. 89, 204; Hollis, 1994, p. 64; Hughes, 1990, pp. 61, 90; Kantorovich, 1993, pp. 39, 59, 61, 175; Koestler, 1969, p. 200; Losee, 1993, p. 121; Miller, A. I., 1996, pp. 79, 93, 97, 205, 337, 351, 369, 445; Newton-Smith, 1981, pp. 62, 211; Pantin, 1968, p. 121; Popper, 1979, pp. 31, 277; Ruse, 1998, p. 46; Thouless, 1953, p. 71+74; Whewell, 1860, pp. 133, 139-146, 174; Wilson, E. O., 1998, pp. 52-53; Ziman, 1978, pp. 22, 24, 30, 31, 88, 91, 101, 132, 139).

- *Thought experiment*, to generate theoretical models by imagining a

Table 7. Content Analysis of Research Metholology textbooks

Authors	Empirical Research Processes	Non-Empirical
Riley, 1963	Experiment (21), document study (21), observation (22), questioning (22), participant observation & questioning (22), qualitative description (22), measurement (23), sampling (283), measurement (328), statistical analysis (404), trend study (550), experiment (612).	Theory extension (27), hypothesis deduction from theory (28).
Rummel, 1964	Sampling (66), observation (84), interview (99), document analysis (163), experimental design (178), scaling (198).	
Williamson et al., 1982	Measurement (63), sampling (103), survey (125), interview (163), participant observation (192), experiment (214), historical analysis (239), content analysis (260), aggregate analysis (260), statistical analysis (377).	
Phillips, 1985	Measurement (107), sampling (175), survey (211), observation (291), experiment (323), simulation (353), cross tabulation (419), statistical analysis (471).	
Neale & Liebert, 1986	Case history (26), sampling (31), measurement (34), survey (49), Mill's methods (91), validity (98), experimental design (134), passive observation (227).	
Bailey, 1987	Measurement (59), sampling (79), questionnaire (104), interview (173), experimental design (213), observation (238), document study (290), simulation (317), statistical analysis (384).	Deductive theory construction (444).
Babbie, 1989	Grounded theory construction (51), sampling (163), experiment (211), survey (235), field observation (260), content analysis (293), secondary analysis (310), historical analysis (317), statistical analysis (368+435).	Hypothesis deduction from theory (39).
Leedy, 1989	Historical analysis (125), questionnaire (142), interview (148), sampling (151), analytic survey (174), experiment (217).	
Sekaran, 1992	Conceptual modelling (63), experimental design (114), measurement (148), reliability & validity (171), interview (190), questionnaire (200), sampling (223), statistical analysis (258).	Hypothesis deduction from theory (79).
Singleton et al., 1993	Measurement (100), sampling (136), experimental design (179), survey (246), field observation (316), using available data (354), historical analysis (373).	Deductive reasoning (44).
McBurney, 1994	Control (141), naturalistic observation (175), participant obser-vation (171), case study (179), questionnaire (194), sampling (202), experimental design (221), statistical nalysis (411).	
Breakwell et al., 1995	Measurement (38), experimental design (50), survey (99), sampling (104), facet analysis (116), questionnaire (174), direct observation (213), interview (230), discourse analysis (243), scalogram analysis (259), historical analysis (314), statistical analysis (338).	Meta analysis (386).
Rosnow & Rosenthal, 1996	Measurement (94), reliability & validity (121), experimental design (143), survey (188), statistical analysis (213).	
Elmes, et al., 1999	Measurement (187), experiment (256), complex experiment (235), small-n experiment (259), quasi-experiment (259), interpretation (299).	
Zikmund, 2003	Qualitative analysis (109), survey (174), observation (234), experiment (256), measurement (292), sampling (368), data analysis (452).	Theory building (40).

Note: The name 'grounded theory' does not actually refer to a deductive explanatory theory, bu rather to a group of related empirical propositions. A more realistic name would be 'empirica model'.

situation and then using its features as premises of an inductive or deductive argument (Azevedo, 1997, p. 56; Brown, 1992, p. 34; Gower, 1997, p. 31; Klee, 1997, p. 60; Miller, R. W., 1987, p. 63; Miller, A. I., 1996, pp. 7, 29, 109, 114, 128, 205, 258, 364, 375; Pratt, 1978, p. 87).

- *Logical deduction*, to explain observable empirical regularities from unobservable first-causes (Azevedo, 1997, pp. 15, 41, 44, 157; Campbell, N. R., 1920, pp. 108, 116, 123, 128, 146; Chalmers, 1982, p. 5; Doyal & Harris, 1986, pp. 94, 96; Gower, 1997, pp. 37, 120, 194; Harre, 1970, p. 15, 1985, pp. 38, 54; Hollis, 1994, pp. 31, 62, 63; Hughes, 1990, pp. 51, 52; Kantorovich, 1993, pp. 28, 64, 66, 127; Klee, 1997, p. 107; Losee, 1993, p. 158; Miller, R. W., 1987, pp. 18, 40, 226; Miller, A. I., 1996, pp. 40, 205, 351, 403, 408; Nagel, 1961, pp. 21, 31, 65; Newton-Smith, 1981, p. 212; Pantin, 1968, p. 100; Popper, 1959, p. 32; Pratt, 1978, p. 84; Ruse, 1998, p. 150; Ryan, 1970, pp. 46, 49, 128, 199, 200; Whewell, 1860, pp. 137, 174, 193; Wilson, E. O., 1998, p. 28; Wuketits, 1990, p. 170; Ziman, 1978, pp. 18, 33, 140).

- *Teleological* methods, to identify human purposes and connect them to human actions (Doyal & Harris, 1986, p. 52-63; Nagel, 1961, pp. 23-25, 401-428, 532-535, 411-418, 422-424;.Ryan, 1970, p. 140)

Therefore *methodologists have indeed omitted many useful research processes and knowledge products.*

Consequently:

The impoverished empiricist textbooks of Research Methology cannot qualify as comprehensive sources of research processes and knowledge products.
Researchers who rely exclusively on those books are likely to find themselves in a methodological rut.
Academic research programs that refer students exclusively to those books may lead the next generation of researchers into a methodological rut.

Research on Research

The prevalence of empiricism casts serious doubts on the methodological recommendations of History of Science, and especially Research Methodology. So there is a need for corrective action.

When people seek practical advice on how to do research, they are more likely to select textbooks entitled 'Research Methods' than textbooks entitled 'Philosophy of Science' or 'History of Science'. They would be justified in doing so because, firstly, the title 'Research Methods' is more obviously relevant to the work of researchers, and secondly, because authors in Philosophy of Science and History of Science rarely aim to provide practical advice on how to do research. So the corrective action should mainly be aimed at the emerging discipline of Research Methodology.

Authors in this discipline could do several things.

- They could try to undermine empiricist cults. The obvious approach is to point out that empirical research alone cannot produce deductive explanatory theories, and is therefore likely to retard progress towards scientific status. A more devious approach would be to manipulate the fashion process. If academic opinion leaders want to retain their leadership positions, they should not be seen to support unfashionable policies (Sperber, 1990). So the leaders might well abandon positivist empiricism if they were to suspect that this doctrine was going out of fashion. That suspicion could perhaps be raised by drawing their attention to some of the criticisms of positivism and empiricism that were quoted above.

- They could try to transform Research Metholology into a *science* by producing an *explanatory* theory of research method.

- Most importantly, they could try to establish a comprehensive classification of needed knowledge products and a corresponding battery of research processes.

To establish the classification of products and the battery of processes, methodologists should not merely *debate is*sues of research, but should practice what they preach, by doing research on research. Hundreds of research projects could be carried out to find new research processes and knowledge products. To begin, these projects could simply import existing processes and products from related disciplines.

- Several processes and products could be imported into Research Metholology from the *History of Science* (Phillips, 1985 p14). The historians describe processes that scientists have actually used (e.g.

Bowler, 1992; Brock, 1992; Cardwell, 1994; Mayr, 1982; Miller, 1996; North, 1994; Pais, 1982; Singer, 1959; Smith, 1997). In particular, they could look for non-empirical methods such as mathematical and logical *deduction.*

- Several processes and products could be imported from the *Philosophy of Science.* For instance, several authors have suggested taking advantage of *analogies* between the systems studied by different disciplines (Harre, 1960, 1970, 1985; Hesse, 1963, 1974; Nagel, 1961; Ryan, 1970).

- Further processes could perhaps be imported from *Cognitive Psychology.* For instance, several authors have described human methods of problem solving and invention (De Bono, 1967-1992; Hadamard, 1945; Polya, 1954, 1957). The aim of most research projects is to solve a problem or a puzzle (Kuhn, 1970, pp. 139, 151, 161; Laudan, 1977; McBurney, 1994, p. 53). The solution often involves invention (Bronowski, 1973, p. 10; Harre, 1970, 1985; Hughes, 1990; Kantorovich, 1993; Ruse, 1998; Whewell, 1860; Ziman, 1978). Therefore these cognitive methods could be used for research purposes. As *hybrids* that include both empirical and non-empirical components, they enable a researcher to tackle a problem both ways.

- Further hybrids could perhaps be imported from *Engineering and Management*, which contain methods such as designing and planning (Brown, 1988; Drucker, 1985; Goldberg & Sifonis, 1994; Peters, 1997; Pollard, 1974, 1978). These methods could be adapted for use in creating new knowledge.

- Further hybrids could probably be imported from *Systems Theory.* Methods such as systems analysis and modelling could be used in solving research problems (Blanchard & Fabrycky, 1981; Checkland, 1981; Cleland & King, 1975; Robertshaw, Mecca, & Rerick, 1978; Schoderbek, Schoderbek, & Kefalas, 1990; Troncale, 1988; Wilson, B. 1990). In particular, Von Bertalanffy (1968) has suggested that a special type of analogy called a *homology* can be used for knowledge transfer between different disciplines.

Conclusion

The previous sections have shown that the empiricist doctrine is dangerause, because it impoverishes research with its absurd claim that researchers should use empirical methods *exclusively*. In particular:

- researchers need knowledge of both the methods of research and the products of research, and this knowledge is available not only in textbooks of Research Metholology but also in the History of Science and the Philosophy of Science

- empirical research merely produces isolated empirical generalisations, whereas theoretical research integrates them into a comprehensive explanatory system, and as 'the whole is greater than the sum of the parts', a broad theory is more useful than a set of isolated generalizations

- inductive empirical research methods are not appropriate for producing deductive explanatory theories, and because the empiricist doctrine restricts its adherents to empirical methods, it confines them to producing the less-useful generalizations, and prevents them producing the more useful theories

- an academic discipline only qualifies for the status of a science when it has progressed beyond empirical generalizations to explanatory theories, and as the empiricist doctrine restricts its adherents to empirical methods, it prevents them from progressing to scientific status

- yet empiricism is firmly entrenched in many academic disciplines; so researchers should ask themselves 'have I been influenced by this doctrine, either wittingly or unwittingly?' - and if so, they should reject it vigorously!

Further work is necessary to assess the extent to which empiricism has entrenched itself in the Information Systems discipline – and still remains entrenched – as also in the other disciplines under the umbrella of Informing Science, and to assess the extent to which it has impoverished previous research – and is impoverishing current research. The present author's personal experience suggests that empiricism has strongly influenced the Information Systems discipline, although its influence is beginning to decline. So there is hope for the future. In particular, someone may soon break out of the inductive empiricist mould and devise a deductive theory of IS that explains the many empirical findings of the previous decades.

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Chapter 22

Routine versus Non-routine Informing: Reflections on What I Have Learned

T. Grandon Gill

Introduction

It is somewhat paradoxical, but doubtless true, that the clients who will be most informed by this book are its editors. For me, in particular, my attempt to become acquainted with the broad spectrum of research that has shaped the informing science transdiscipline over the past decade has totally changed my thinking. In the early stages of the book, these efforts at understanding led to a series of papers in *Informing Science: The International Journal of an Emerging Transdiscipline* (*InformSciJ*) titled "Monograph on Complex Informing Systems". Several of these papers were subsequently revised to become chapters in this book. It was in the later stages of preparing the book—during the process of studying each accepted chapter line by line—that my thoughts about the field were truly transformed, however. These new thoughts are the subject of this chapter.

The engine that has driven my new understanding has been the need to find unifying themes in the nineteen chapters that constitute parts I through IV of this book. This proved to be no trivial task. On the one hand, we had the theoretical work of Zbigniew Gackowski (Chapters 4 and 10) and of Christozov, Chukova and Mateev (Chapter 11). This stream involves a perspective on informing close to that taken by economists and decision scientists—the area of my undergraduate and much of my graduate training. Similarly familiar to me were studies grounded in traditional MIS concepts, such as Koohang's empirical study on usability (Chapter 5). At the other extreme, however, we had the contributions of Knox (Chapter 6), Hans-Erik Nissen (Chapter 13) and Bednar & Welch (Chapter 14) which draw upon a set of concepts grounded in areas of philosophy with which I was almost entirely unfamiliar. Unfortunately, these two streams seemed to be drawing nearly opposite conclusions with respect every common topic.

And there were the case studies. What common themes could be distilled from Jim Everett's system for enhancing bauxite mining (Chapter 14), Bob Travica's history of a folk festival (Chapter 15), Spacic and Nesic's examination of how TV news flowed despite the attempts of a restrictive Serbian government to suppress it (Chapter 16), Wang & Lu's investigation of cyberdating in China (Chapter 17), Miliszewska & Tan's description of the evolution of a student-developed web-based portal project (Chapter 18) and, lastly, Singh, Hawkins and Whymark's study of the processes that occurred when a group decision support system was used to design a curriculum exercise (Chapter 19)?

Finally, I felt the need to present whatever common themes I was able to distill from the chapters using existing informing science frameworks, most notably those proposed by Eli Cohen at the outset of the discipline (Chapter 2) and slightly expanded by my colleague, Anol Bhattacherjee, and me a few years ago (Chapter 3). Naturally, I asked the book's many contributors to undertake linking their work to these frameworks as part of revising their earlier research to make it suitable for the book. In some cases this proved straightforward. In others, however, it proved nearly impossible for them, and later, for me.

How I ultimately resolved this challenge was to draw, not surprisingly, upon a concept that frequently appears in my own research, that of *structural complexity*. Described in far greater detail in Chapter 7, this particular class of complexity definition views the construct as a continuum based upon the familiarity of the task, whose opposite poles are *routine* and *non-routine*. What I will now do, in the remainder of the chapter, is three things:

1. Explain how the book's chapters can be characterized according to their position in the routine-non-routine continuum

2. Examine what the chapters tell us about the differences between routine and non-routine informing systems

3. Consider how the foundations we have laid over the informing science transdiscipline's first decade may serve to inform and guide our research over the next decade.

Routine, Non-routine and Critical Perspectives

Just as there exists a continuum of tasks from the routine to the non-routine, the same can be said for informing systems. For our purposes, any informing system established to provide a well-defined body of information to clients on an ongoing basis can be characterized as routine. Such a system often involves technology, but technology is not a prerequisite for routineness. The more an informing system departs from the routine model, the more complex it is. I will also argue that the informing processes that take place during transitions from one routine system to another—such as those described in Travica's Folklandia study (Chapter 16)—are necessarily complex.

Table 1: Chapter Classification			
TYPE	**ROUTINE**	**CRITICAL**	**NON-ROUTINE**
Theory	2. Ugly Duckling, Cohen 4. IS for Operations, Gackowski 5. Useability, Koohang 10. First Principia, Gackowski 11. Misinforming, Christozov, et al.	6. Conflicting Notions of Information, Knox 7. Task Complexity, Gill & Hicks 8. Utility, Gill 9. Resonance, Gill 12. Rugged Fitness Landscape, Gill 13. Use and Redesign of IS, Nissen 14. Inquiry into IS, Bednar & Welch	
Case Example	15. Bauxite mining, Everett		3. Crossroads, Gill & Bhattacherjee 16. Folklandia, Travica 17. Informing Citizens in Serbia, Spacic & Necic 18. Cyberdating, Wang & Lu 19. WebAce, Miliszewska & Tan 20. Collaborative Knowledge Building, Singh et al.

Using this continuum, it is possible to classify quite a few of the chapters of this book, as shown by the *Routine* and *Non-routine* columns of Table 1. There are also quite a few chapters that consider both routine and non-routine perspectives. I refer to these as the "critical perspective" chapters because, for the most part, they point out inadequacy inherent in routine informing system models, thereby explicitly or implicitly seeming to advocate a model suitable for addressing the complexity of "real world" settings. For these, then, I added a *Critical* column between Routine and Non-routine. It is also relatively easy to characterize whether a chapter is theory focused, relying heavily on reasoning and references for its contributions, or case focused, relying heavily on a particular real world example. This breakdown is represented by the rows in Table 1.

One observation that immediately jumped out at me as I constructed this table was the non-random appearance of the chapter distribution. Most notably, all the economic models and IT-focused research clustered in the Theory-Routine block, whereas nearly all the case examples ended up in the Non-routine columns. The only exception to this last observation was Everett's case study of a system to improve bauxite mining (Chapter 15); this is important because it refutes any possible supposition that routine informing systems do not exist. Indeed, later in this chapter I will argue that such systems are probably vastly more common than we would conclude from a survey the research literature. But, it is probably fair to say that such routine systems typically do not generate a lot of excitement among researchers. Perhaps that is because they often work reasonably well without our help or involvement.

When I first constructed Table 1, it occurred to me that I might learn something by comparing the characteristics suggested by the chapters in the Routine column with those of the Non-routine column. At the time, I had no suspicion how large that list would become. Within a few hours, I had over a dozen entries and had no doubt that the list would continue to grow the longer I thought about it.

In the next section, I present the list of characteristics that may help us to distinguish "routine" from "non-routine" informing systems and, in the process, better understand the diversity of research in the informing science transdiscipline. Let me emphasize, once again, that these are not discrete states but, rather, end points on a continuum. Thus, it would rare to find a real system that is a pure routine or non-routine exemplar.

But I believe the extremes provide a useful starting point for comparisons.

Informing System Characteristics

To organize this rather lengthy section, I divide my observations into four general categories:

1. *Structure*: Those characteristics that define the structure of the informing system.
2. *Behavior*: How a system of one type or the other can be expected to behave as the informing process continues and as the system evolves.
3. *Performance*: The goals we establish for the system and how informing success is determined.
4. *Research*: Issues relating to how we might best research these systems in order to gain a better understanding of them.

I now present a section on each category.

Routine vs. Non-routine Structure

At the two extremes, routine and non-routine informing systems seem to diverge considerably. For routine systems, the basic model that Cohen presented in Chapter 2 often holds very well, i.e.,

Informer → Channel →Client

As informing needs become more complex, however, structures diverge from this considerably. I now make some specific observations on the subject of structure.

> *1. Routine informing systems tend to be driven by the needs and requirements of the clients and the skills of the designers; non-routine systems evolve through cycles of interactions with stakeholders.*

Some of the most successful informing systems in the history of IT, such as the airline reservations systems and many accounting systems, were designed and developed with few—if any—of the considerations for enlightened helical design processes described in Nissen (Chapter 13) or Bednar and Welch (Chapter 14). By the same token, however, I can also identify a number of failures—including one or two of my own efforts—that would have benefited from a more inclusive and reflective design process. In considering how to tell the two apart, I suspect—and this is a conjecture, rather than an assertion—that there are two particularly important considerations: the narrowness of the task context and the number of clients (a.k.a., users) being informed. Narrow task contexts tend to limit the number of ways that participants can think about the task. A large number of clients implies that achieving consensus through iterative cycles is likely to be a never-ending process—in much the same way that it is virtually impossible to design a course that is optimal for all the students who enroll in it.

Where routine informing is the object of a system, the three levels that Cohen proposed—informing instance, instance creation, and design—are likely to map very well to the process by which informing systems are constructed. As systems become complex, however, the processes of operation, construction and design become so intermingled that the levels almost impossible to distinguish.

I would emphasize here that I am most definitely not arguing against user involvement in the design of routine systems. To the contrary, in our routine system exemplar provided by Everett in Chapter 15, he strongly asserts the need to consult users. The design process he described was not particularly iterative, however. Rather, it involved consulting experts and users at the outset, after which the system was constructed. Subsequently, it was left alone for routine use by the client. Contrast this with the continual adapting of Serbian journalists in their efforts to thwart the aims of a repressive government intent on preventing free flow of information, as described by Spasic and Nesic in Chapter 17.

> *2. Routine informing systems tend to follow the informer → client model; non-routine systems involve flows between clients and across system boundaries.*

This particular observation can be illustrated by contrasting the bauxite mining system (Chapter 15), where informer and clients were clearly defined with the group decision support system (GDSS) that enabled collaborative learning processes described by Singh, et al. in Chapter 20, where you had clients in the exercise preparing for the day they would become informers, or Miliszewska and Tan's WebACE case, where the roles of client and informer kept swapping during development.

More generally, in Chapter 9 I point out that client-to-client informing is virtually ubiquitous in the process transferring complex ideas to a large client community—an assertion almost universally supported by a long and impressive body of research relating to the diffusion of technology and ideas.

> *3. Routine informing systems tend to have well defined structure and boundaries; non-routine systems tend to have neither.*

This can be viewed as nearly definitional in nature, but comes as a natural consequence of increasing structure. I discuss the process of knowledge structuring in Chapter 9.

> *4. Routine informing systems tend to map to a data → information → knowledge flow; non-routine systems exhibit patterns that are much harder to characterize*

With clear directionality, structure and design, traditional models whereby data is processed into information that is then incorporated by the client into knowledge—sometimes characterized as conduit or linear models—provide an adequate mapping. As Knox discusses in Chapter 6 and as implied by the discussions of Nissen (Chapter 13), along with those of Bednar and Welch (Chapter 14), attempting to do so in the context of non-routine informing leads to significant philosophical and practical quandaries.

> *5. Routine informing systems tend to converge towards dedicated technologies and channels; non-routine systems tend to spread out across technologies and channels*

Travica's Folklandia Festival (Chapter 16) provides a nice example. In order to break free of insider control, outsiders had to seek out new channels and patterns of interaction. A similar effort to establish multiple new pathways can be found in the efforts of moving news through government controlled networks, described by Spasic and Nesic in Chapter 17.

An interesting possible corollary to the observation is that when a channel is maintained for the express purpose of routine informing, we can expect non-routine informing systems to attempt to co-opt part of that channel for their own informing purposes, as was the case for the Serbian government-controlled ISDN network. Personal use of the internet during business hours and the file sharing that goes on over many university networks might be offered as other examples. This tendency of non-routine informing systems to spread out across channels would naturally tend to make them more resilient in the face of efforts to shut them down. This particular hypothesis resurfaces later in the chapter, when we consider the adaptability of non-routine informing systems.

> *6. The structure of routine informing systems tends to be driven by the task being performed; non-routine systems are organizationally situated and their structure cannot be predicted or explained without understanding the broader environment and the community of users*

If we look at Everett's bauxite mining systems (Chapter 15), we find nearly all the narrative relates to the task being performed. If you understand the task, you understand the system. In virtually all the remaining example chapters, much more consideration of the context and individuals involved is required; without that context, the nature of the resulting systems just would not make sense.

Routine vs. Non-routine Objectives

In the seminal article that launched the informing science transdiscipline (Chapter 2), Cohen implicitly specified the objective of informing systems as being:

> "[to] provide their clientele with information in a form, format, and schedule that maximizes its effectiveness."

In this section, I make some observations with respect to how the objectives of routine and non-routine informing systems tend to diverge.

> *7. The objectives of routine informing systems are based around the performance of a particular task or set of tasks; objectives in non-routine systems are much more closely related to client roles and the social context of informing.*

To illustrate the distinction, contrast the clear purpose of Everett's bauxite mining systems (Chapter 15) with that of the Serbian case study (Chapter 17), where participants continually innovated and improvised in their role as providers of uncensored information to the populace. In Travica's Folklandia Festival case, the insiders specifically prevented the development of written records and documentation, which would have routinized the tasks of organizing and running the festival, in order to maintain their central power role.

> *8. Incremental informing normally leads to incremental improvements in performance for routine informing systems; in non-routine systems, incremental informing often results in misinforming.*

In Chapter 4, Gackowski presents a figure showing how utility (value) typically rises as additional information is acquired. This makes sense in a routine informing context because all information is going into predefined slots. In other words, you know what you know *and* know what you don't know.

The situation is much less clear cut when informing is complex. As I talked about in the filter model presented in Chapter 9, there are many cognitive biases that interfere with the interpretation of low structure informing messages. An excellent discussion of the challenges such ambiguity presents can be found in Wang and Hu's discussion of cyberdating (Chapter 18), where the difficulty of determining intent from incomplete communication is readily apparent. As a consequence, sometimes a little informing will prove worse for the client than none at all.

An interesting example of this can be found in Christozov, et al.'s chapter on warrantee and misinforming, Chapter 11. In their experiment, some participants were given a choice between a 90 day trial period, with free return, and a 3 year warrantee on a hypothetical PC. A second group of participants was given the two original options plus a third option, consisting of a 30 day trial and 1 year warrantee. That third option was verifiably suboptimal, given the description of the situation that had been given to the subjects. Nonetheless, many of them chose it. In doing so, they fell victim to a well known phenomenon known as the compromise effect, whereby decision makers will gravitate towards compromise options even when rational choice might dictate otherwise. In my chapter on utility (Chapter 8), I describe why we would expect such poor choices to be less likely for routine activities.

> *9. The intended outcome of routine informing is normally purpose-focused activity; non-routine systems tend to support multiple, and often interrelated, goals.*

In Chapter 7, Richard Hicks and I point out how tasks can be defined in terms of prescribed activities, goals or a combination of the two. In Chapter 8, I then go on to discuss how familiarity with a task tends to cause goal-based utility to evolve to a state where performer satisfaction is based upon activity. In this context, it then makes sense for Gackowski, in Chapter 4, to view informing in terms of measured effect on the actions of the recipient. By the same token, usability properties, such as those suggested by Koohang (Chapter 5), are best assessed when the purpose for which the system is being used is known.

As goals become more complex, however the direct relationship between informing and action seems likely to break down. In the Serbian media case (Chapter 17), for example, it was not clear what—if any—direct action was intended by the journalists determined to get accurate stories out to the general public. Providing citizens with a clearer view of what was happening in their country and the world was the rather amorphous objective. What action, if any at all, was to be taken as a consequence was not planned by the informers.

> *10. Routine informing systems depend upon, and strive to instill, a specific mental model in the minds of clients; in non-routine systems, creating a specific model is not necessarily intended.*

If the intention of informing is to produce specific actions, as proposed above for routine systems, it would make sense to attempt to instill a particular model in the mind of clients. In Everett's system (Chapter 15), it was an economic model of bauxite production. In the case of the Serbian government (Chapter 17), and other repressive regimes—such as the inside circle in Travica's Folklandia Festival (Chapter 16)—it was a particular model of how the world worked that was consistent with the informers maintaining their power.

Non-routine informing frequently involves flows of information that are not necessarily intended to produce a particular model or problem space (a term I describe in greater detail in Chapter 14). In fact, constructivist approaches to learning, as mentioned in Knox (Chapter 6) are based on the premise of each individual developing a distinct model that he or she "owns".

This particular distinction resonates with me since it could be used to describe the two polar opposite courses that I regularly teach. On the one hand, I teach an undergraduate programming course that is heavily multimedia based, changes little from semester to semester and where I have a goal of teaching students a very specific mental model that is useful for programming. I measure my success through student action, in the form of projects handed in and correct answers to multiple choice test questions. At the other extreme, I teach a case method course to graduate students that is the capstone for our MS-MIS program. Here, the principal basis of evaluation is student participation in class discussions of a set of cases that I change frequently. I have no particular mental model in mind that I want students to develop. That does not mean, however, that the latter course is without goals. Rather, it means the goals are a blend of enhancing their communications skills, improving their reasoning ability and demonstrating techniques for synthesizing and evaluating complex situations—techniques that I could not articulate in any comprehensible way despite my ability to apply them.

> *11. Routine informing systems support a specific goal or set of goals shared by all clients; non-routine systems tend to support a diverse, heterogeneous set of needs.*

This is largely a function of the task specificity of routine informing systems, which tend to revolve around well defined tasks (see observation 10). Once again, contrasting the goal specificity of Everett's bauxite mining system (Chapter 15) with all the remaining system examples should provide ample support for this observation.

> *12. Routine informing systems tend to support task performance and efficiency; non-routine systems best support a need for adaptability.*

This argument, presented in my Chapter 12, draws upon a rugged fitness landscape model from evolutionary biology and considers its implications for informing. Under this model, routine informing could be characterized as selecting a particular peak and seeking to reach the top. Recall, in this context, Cohen's original "information in a form, format, and schedule that maximizes its effectiveness." This particular characterization of informing success makes complete sense where a system accomplishes routine informing.

Non-routine informing, on the other hand, frequently involves multiple, interrelated goals. I discuss the implications of this, at some length, when I consider the nature of the utility function (Chapter 8). As a consequence, where there are multiple clients and informing needs are not strictly related to a single task, chances are that clients will end up adapting the system so as to make it useful for pursuing different objectives. In fitness landscape terms, that means the clients will be distributed across multiple peaks.

In evolutionary theory, distribution across multiple peaks corresponds to diversity. While diversity is not necessarily efficient, it does tend to be much more adaptable when the environment changes. Kauffman (1993) believes that such a tradeoff is fundamental: for life to exist it must find a balance between order (a single peak resulting from a completely decomposable landscape that is highly vulnerable to landscape changes) and chaos (where landscapes are so rugged that it is nearly impossible to find combinations of high fitness). To demonstrate the value of adaptability, in Chapter 12 I give the example of the Irish Potato Famine. At the time, growing a single crop—the potato—for a large portion of Ireland's nutrition was economically efficient, owing to the country's favorable climate. Then blight affected the entire crop, leading to mass starvation. Had farmers relied on a more diverse set of crops prior to the blight, the famine would have been far less severe. But they would also have been less prosperous prior to the blight. In Chapter 3, Bhattacherjee and I provide another example: the MIS research discipline. MIS research, we argue, has developed an extremely narrow focus: our measure of success is limited to publications in top ranked journals, we employ a limited number of research methods—drawn almost entirely from the logical empiricist perspective, discussed by Nissen in Chapter 13 and by Bednar and Welch in Chapter 14—and, most critically, we treat ourselves (i.e., other MIS researchers) as our only clients. As a consequence of this narrow focus, when MIS experienced a major external shock in the form of a sudden and precipitous drop in student enrollments starting in 2002, the health of the research discipline (measured in terms of resources made available to it) fell rapidly.

Based on these arguments, we should expect non-routine informing systems to be more resilient than routine systems in the face of a dynamic environment. The ability of the Serbian news systems to keep performing its mission through continuous adaptations in the face of a very hostile environment (Chapter 17) illustrates the adaptability potential of non-routine informing systems.

Routine vs. Non-routine Behaviors

Another area where I saw divergence as informing system complexity increases was in general patterns of behavior. I will outline a number of these now.

> *13. Routine informing systems tend to perpetuate themselves; non-routine systems necessarily transform themselves.*

This observation first occurred to me as I was reading Spasic and Nesic's chapter (Chapter 17). It seemed to me that if the system were successful in its mission of informing the Serbian people, the ultimate result would necessarily be regime change. Were that to happen, then the next logical consequence would a radical change in the informing environment, leading to a further need for adaptation by the system. In other words, the system necessarily transforms itself.

As I thought about the other examples, as well as the theoretical work of Nissen (Chapter 13) and Bednar and Welch (Chapter 14), I wondered if tendency towards self-transformation might actually be a general property of non-routine informing systems. Conceptually, the idea makes sense. Non-routine informing tends to produce major changes in client mental models. After the change, it is doubtful that the original system will be structured to best inform the client's new state.

What I found particularly interesting about this observation—and perhaps the reason I found it to be novel—was that more than a decade ago, I wrote an article about two well known informing systems (at Batterymarch Financial Management and Mrs. Fields Cookies) that had rendered their respective companies unable to adapt in the face of changing environments. As a consequence, both companies nearly collapsed when environmental changes occurred. Both systems were also nearly textbook examples of what I am calling routine informing systems. The Batterymarch system used contrarian models of stock prices to implement the first automated trading system; the Mrs. Fields system directed the day-to-day activities of all the workers in its stores. Thus, I find myself proposing that routine systems resist change.

> *14. Routine informing systems tend to be stable; non-routine systems migrate towards greater structure.*

An obvious question raised by observation 13 is in what direction non-routine systems migrate. What I observed in our examples is that many of the systems we explored seemed to be gravitating towards greater structure. For example, as the Folklandia Festival (Chapter 16) system transitioned towards its later form, procedures were developed and record keeping was instituted. As Serbia changed its government, more routine and efficient patterns for news distribution became possible.

Once WebACE (Chapter 18) was completed, it became a relatively straightforward system that instructors could use to provide information to students. The use of the ZingThing™ system described in Chapter 19 was expressly for the purpose of developing more structured exercises.

From a cognitive model standpoint, there would be considerable reason to predict that non-routine informing systems would tend to migrate in the direction of more structure. I describe a similar migration towards greater structure for both utility (Chapter 8) and problem space knowledge (Chapter 9). Weighed against this, however, would be the expected impact of environmental turbulence. Thus, I would only conjecture that migration towards greater structure will be limited to periods when the informing environment is relatively stable.

> *15. Routine informing systems adopt familiar communications patterns; non-routine systems continually seek a variety of patterns and paths for communications.*

The first half of the observation is largely definitional, since familiar and routine have very similar meanings. As I think about it, I recall my time as a naval submarine officer where I was repeatedly coached to use precisely the same wording each time I gave a routine order, such as "Make your depth 100 feet". Knowing that routine informing will consist of a limited repertoire of messages increases the speed and reliability with which information can be transferred.

The second half of the observation is best illustrated by Wang and Lu's cyberdating example (Chapter 18), where the computer-based channel used by potential couples to communicate was insufficient to ensure compatibility and validity of communications. Other forms of communications, most notably face-to-face meetings, were an essential part of the process. In fact, if my own experiences—of more than two decades ago, I hasten to add for the benefit of my wife—are any indicator, even the face-to-face dating process often involves seeking out a wide range of different contexts and activities through which the couple mutually informs each other. What needs to be conveyed is complex, and variety in the process helps.

> *16. Routine informing systems have mechanisms for guaranteeing client attendance to the channel; for non-routine informing systems, client attendance is rarely assured.*

Cohen's original concept of informing, presented in Chapter 2, refers to information being conveyed in a particular "form, format, and *schedule*" [italics are mine]. That perspective illustrates how ensuring attendance of the informing channel—the precursor to paying attention to the channel—is central to routine informing.

With respect to non-routine informing, Chapter 9 begins with a historical case study involving a Naval Officer around the turn of the 20th century who was trying to get the U.S. Navy to adopt a vastly more effective technique for aiming guns from a ship. His first effort involves sending letters to the appropriate authorities. These letters were promptly filed, unread, and were subsequently consumed by cockroaches. When non-routine informing is conducted, ensuring that the client is attending the channel and paying attention to the message can be highly problematic. Mere presence of a client in the channel does not guarantee either. I'm sure any of us who have looked out over our students in a lecture-style class will vouch for that assertion.

> *17. Routine informing systems are robust in the presence of noise and minimally impaired by client filters; informing in non-routine systems can be degraded by noise and is heavily influenced by filters.*

Both routine and non-routine informing systems rely heavily on preexisting client models to work in conjunction with messages in order to achieve understanding. In routine systems, models are very similar between sender and client (see Observation 10) and messages are sufficiently structured so that they can be repeated to confirm reception.

In non-routine informing, the sender tends to have limited knowledge of the existing mental models that will be used to construct understanding by the client. That immediately increases the likelihood of distortion by client filters (see Observation 8). In Chapter 9, I provide an example where a U.S. naval officer's statement that the British used certain equipment was interpreted as meaning that he thought the British navy had better equipment than the U.S. navy. This interpretation led the client of the original communication to send back a strong denial of the assertion and a stinging reprimand for the officer. Where sender and client models are very different, even if a message is repeated back word-for-word there is no guarantee that it was interpreted as intended by the sender.

Routine vs. Non-routine Research

The very different nature of routine and non-routine informing systems has important implications for the types of research activities best suited to each. In this section, I look at some of the differences that seemed to emerge as I read the chapters of the book.

> *18. Routine informing systems will generally offer a variety of measures that can be used to assess system performance directly; the performance of non-routine systems will require indirect assessment approaches and will often require studying the historical and organizational context.*

In Gackowski's two contributions to the book (Chapters 4 and 10), we see the thoughtful development of a model of informing for operations, paying careful attention to the assumptions, necessary conditions and contributions of information factors. That model is very much directed towards a view of informing in terms of the actions it produces. He also very specifically limits the domain to which the model can be applied, that of well defined situations. For at typical routine situation, many metrics of performance could be applied—such as contribution to profitability, usage (if IT is involved in the system), contribution to quality, and so forth. How the operational measures of performance should be weighted in a given context will not necessarily be obvious. Indeed, Gackowski points out that how we assess quality will necessarily be situation-specific. The Everett study of bauxite mining (Chapter 15) provides an excellent demonstration of that specificity. It also makes it clear that we should be careful not to equate "routine" with "simple". Rather, the routine informing system can provide rich opportunities for research and model building.

For complex situations, it is very likely that objective measures of performance will be much harder to come by. To begin with, the tendency of informing in such systems to spread across channels will complicate data gathering. Where multiple clients are involved, the benefits of informing to one client will not necessarily be replicated for other clients; indeed the differences between initial client mental models will almost guarantee that they will not. Non-routine informing also tends to be highly situated in an organizational and environmental context (see Observation 7). Thus, taking an isolated view of task performance is very unlikely to provide a complete or accurate picture. Instead, we will typically need to understand the context in which the system evolved in order to understand its eventual structure and benefits. History can be a valuable guide in this respect, since each successive adaptation represents an attempt at improving informing fitness. Thus, the entire adaptation process can be considered as a series of informal experiments conducted by system participants. This is evidenced by the richness of the descriptions of the processes associated with nearly all the case examples presented in Part 4. Only the routine bauxite mining system example (Chapter 15) offers little detail on the process through which the system was created. But, in the case of a task-focused routine informing system, understanding the detailed history of the system is not a prerequisite for understanding how it informs.

19. Routine informing systems tune themselves to particular fitness peaks; non-routine systems tend to support multiple peaks simultaneously.

In the conceptual model that I described in Chapter 12, even if a particular task exists on a rugged fitness landscape—meaning that there are many alternative approaches to task performance that can be applied successfully—a routine informing system is typically built around maximizing performance with respect to one of these peaks. This can be viewed as a logical consequence of Observations 10, 11 and 12.

As discussed in Chapter 12, the rugged fitness landscape consists of many local maxima, as suggested by Figure 1. In a multi-client informing environment, we may anticipate that clients will be somewhat distributed across the environment, seeking different peaks in many cases. As instructors, we run into this situation in the classroom frequently, with different students having differing objectives for the course; these might include passing, getting an A, learning the material with an eye towards future application or even learning the material for the sake of self enlightenment.

One of the central arguments presented in Chapter 12 is that it can be misleading to combine observations from clients seeking different peaks. To offer a hypothetical example, consider what might happen when a group presentation is assigned to students without specific directions as to how to create it. If my own experience is any guide, there seem to be two generic strategies that are commonly applied. One is to work together to produce a cohesive presentation. The other is to divide the sections of the presentation up, each student then presenting his or her own portion with no effort being made to integrate the parts into a whole. The first strategy tends to inform participants on the nature of group dynamics and provides each member with a complete picture of the topic. The second strategy demonstrates the efficiency benefits of division of labor, while leaving the participants no better informed with respect to group dynamics and with only a partial grasp of the content presented. In other words, employing the second strategy involves learning how to create mediocre presentations quickly.

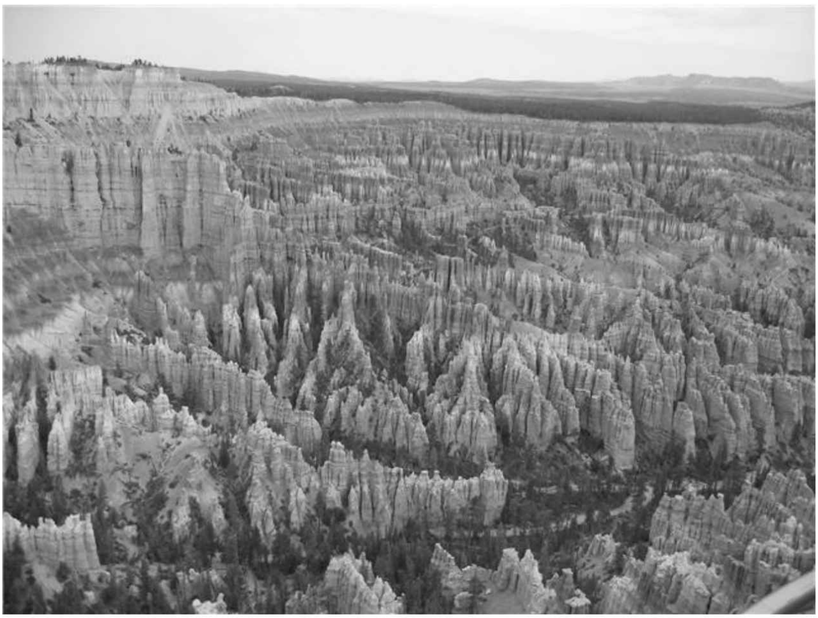

Figure 1: Bryce Canyon, a very rugged landscape (Photo by Grandon Gill)

If, for the sake of illustration, I were then to assume that I could measure learning with perfect accuracy and that my class evenly divided between the two strategies, I might reasonably conclude that group presentations had no value based on an average of the outcomes: the half of the class that benefited from the exercise (those employing strategy 1) being cancelled out by the other half that actually acquired dysfunctional techniques for preparing presentations (those employing strategy 2). It is only through careful study of the two peaks—the "quality" peak and the "efficiency" peak, as it were—that I can understand the different processes at work and, possibly, devise policies to make the second peak less attractive.

Actually, the rugged fitness landscape presents even greater pitfalls to those who do not understand the terrain. Terry Sincich and I (Gill and Sincich, 2008) simulated what happens when observations drawn from a rugged landscape are subjected to a typical multivariate analytical technique (multiple regression). What we found was that as entities on the landscape migrate to local fitness peaks, substantial spurious significances begin to appear. Without an understanding of the underlying landscape structure, it would be easy to misinterpret these as meaningful patterns in what was actually random data (much like our earlier "average" suggests no effect in the previous hypothetical example—disguising the fact that there were actually two strong effects: highly beneficial for one group and equally counterproductive for the other group). Thus, Sincich and I concluded that quantitative analytical techniques should not be applied to predict fitness or test theory until a clear qualitative picture of the landscape is in place.

> *20. Routine informing systems are particularly amenable to analysis grounded mainly in logical empiricism; non-routine systems are better understood through mostly adopting a hermeneutical-dialectic perspective.*

One of the most interesting things I found as I helped select chapters for this book and later began to edit them was the degree to which my own study of the implications of rugged fitness landscapes (Chapter 12) mapped to existing philosophical perspectives on inquiry. For example, when a landscape is fully decomposable it makes sense to:

- Treat the properties of the fitness landscape as a given, which is to say as the underlying reality that ultimately determines the models and theories that we are attempting to uncover through our research.
- Separate phenomena being investigated from their environment. This is true since the environment (which is to say, variables outside of the task) exert an influence independent of task variables.
- Ignore variables that cannot be measured, such as the characteristics of the mental models of the participants. We recognize, of course, that these variables certainly have the ability to impact fitness. Nonetheless, since their impact is

independent of other sources of impact, it is convenient to treat them as a contributor to the error term, along with all other unmeasured variables.

- Demand researcher objectivity, since those variables that cannot be measured objectively can be treated as part of the error term. Ideally, the quality of research results can be determined from a description of the protocol, rather than depending on the observational and interpretive capabilities of the researcher.

- Develop simple, compact theories based upon observation or mathematics, knowing that they will generalize well across the landscape.

- Ignore history, since our principal interest is in examining processes that have reached equilibrium or identifying the forces that drive a system towards equilibrium at a point in time; these are the domains in which our theories will be most predictive.

- Gather large samples that can be statistically tested, these are favored over in-depth analyses of individual situations since the statistical properties of such samples can be tested objectively.

As it turned out, these proved to be more or less the same principles that guide the perspective of logical empiricism (LE), readily evident when they are compared to Nissen's Table 1 in Chapter 13 and Bednar and Welch's Table 1 in Chapter 14.

For highly rugged landscapes—many variables, many interactions, continuous changes to fitness as a result of the influence of co-evolving systems—an entirely different approach is required. Essentially, it is the reverse of what is appropriate for decomposable landscapes:

- Since the fitness landscape changes continuously, change processes, rather than the underlying landscape equation, are better subjects for investigation.

- All phenomena are situated in their environment and cannot be examined independently of it.

- Where individuals participate in the process being investigated, their perceptions and mental models must be taken into account if they contribute to the process. Unlike the decomposable case, unknown terms that participate in an interaction cannot be treated as part of an error term whose size in bounded. In theory, changing a single element that participates in an interaction could change fitness to a new value anywhere in its entire range (see Chapter 12).
- Subjectively measured variables cannot be ignored if a process is to be understood (see previous bullet). The skills of the researcher as an observer and interpreter are therefore critical if rigor is to be maintained and therefore become an integral part of the research method.
- Theories will necessarily become very large, to account for interactions, and of limited generalizability.
- History becomes a critical tool in understanding how to achieve fitness, since it provides one of the few windows available on how changes to variables impact outcomes (see Observation 18).
- Owing to the number of variables involved and the need to acquire information on characteristics that require subjective assessment, in-depth analysis of individual observations is favored over statistical analysis of large samples (that are subject to serious misinterpretation in any event; Gill and Sincich, 2008).

This particular approach to research, in turn, comes very close to the hermeneutic-dialectics (HD) perspective described by Bednar and Welch (Chapter 14) and Nissen (Chapter 13).

The routine-non-routine continuum presented in this chapter highlights the need for both the LE and HD perspective. There are three reasons for this:

1. Routine informing systems, even if created in a complex informing landscape, will normally be designed around a particular fitness peak. As I discussed in Chapter 12, data consisting of observations gathered solely in close proximity to a particular peak tend to be much better behaved from an

analytical standpoint—as long as we don't expect them to generalize too far. Thus, LE approaches may be highly useful in this context.

2. The routine-non-routine distinction is presented as a continuum, not a dichotomy. Therefore, we can expect both approaches to apply to a limited degree in nearly all cases, so long as the strengths and weaknesses of each are carefully considered.
3. Non-routine systems tend to migrate towards routineness when the environment is not too turbulent (Observation 14). We therefore benefit from understanding how to analyze both

The Next Decade of Informing Science

A few years ago, my colleague Anol Bhattacherjee and I wrote an article, the basis of Chapter 3, speculating about how informing science could improve its effectiveness as a research transdiscipline. In this section, I will consider how what I have learned in editing this book has refined and reinforced my thoughts.

The most important insight I have gained can be stated as a simple proposition:

> *The informing science transdiscipline must serve as both a routine and non-routine informing system.*

Based on what I have presented in this chapter, this short statement has some very important implications. Among these:

1. The central purpose of informing science is informing its clients. This cannot be accomplished effectively without some routine informing
2. Diversity of clients is an integral part of any non-routine informing system and serves as an important source of its adaptability, which is the strength of non-routine systems
3. The social context that we create for ourselves will strongly influence the effectiveness of our informing and the processes through which informing takes place

4. To accomplish our informing task, we must utilize every channel we can access and we must continually seek out new channels
5. Understanding how we are evolving is a critical element of the informing process
6. We must rely heavily on our own measures for assessing our progress in our informing activities
7. If we are not careful in our informing activities, the risk that we will misinform is great.

I believe that the long term success of informing science requires us to embrace these characteristics. When reading Cohen's Chapter 2, it becomes clear that informing science was established—at least in part—in reaction to what the MIS discipline was becoming. In Chapter 3, written nearly a decade later, makes it clear that MIS has proceeded even further down that path. If I were to characterize the MIS research discipline today, I would assert that its informing activities are directed almost entirely towards other MIS researchers (including MIS PhD candidates). It employs only two major channels for that informing, conferences and refereed journal articles. Of these two channels, only print versions of the latter, published in a small number of top ranked journals, actually contribute to the measured fitness of an individual researcher. The only philosophical perspective MIS finds acceptable, at least in the U.S., is logical empiricism. We also conclude, in Chapter 3, that MIS is presently in a precarious state, owing to its inability to adapt to changing circumstances in the broader IT economy that effected its student enrollments. In other words, the MIS research discipline has moved so far towards routine informing that its consequent lack of adaptability has left its very survival is in doubt.

Fortuitously, informing science seems to have moved in very much the opposite direction since its initial inception. Our original models, such as those presented by Cohen in Chapter 2, were very much directed towards better understanding routine informing systems. Contrast these with the vastly more inclusive view taken by Cohen at the end of the book, in Chapter 23. In the early days of the field, there was the implicit understanding that we were discussing technology-enabled informing systems. That particular preconception has largely been abandoned. The number of disciplines that contribute to informing science continues to grow—witness the huge range of topics included in the chapters of this book. We also continue to expand the types of publications we use in our informing activities. Under the auspices of the Informing Science Press, books—such as this one—have become an important component of our informing activities and we are adding new channels, such as repositories of learning objects. Our conferences provide another important channel, particularly since their international character and multidisciplinary attendance encourages individuals with the broadest possible range of perspectives to come together. Study missions before and after the conferences encourage the development of informal informing channels. Obviously, technology will continue to make new channels for informing possible—witness the impact of new informing sources, such as Google™, Wikipedia™, Second Life™ and social networking sites. We need to expand into existing channels such as these, as well as devising new channels of our own.

Mentorship as an Informing Channel

One particularly important channel that we have emphasized since the inception of informing science is mentorship. I believe that we need to redouble our efforts in this direction, particularly as they relate to our review and editorial processes. Somewhat analogous to grading, the review and editorial process can be viewed as serving two functions. The first is quality control—preventing work of inadequate rigor or quality from being published. The second is to motivate authors to improve their work and, whenever possible, aid them in better understanding the implications of their findings and in better presenting those findings to their intended audience. In the case of routine informing, the quality control function may well predominate. For example, the multiple choice test is a tool well suited to assessing if routine informing has been successful. Using such a tool, it is the client's resulting score that is most generally of interest to the informer.

Where non-routine informing is taking place, the motivational and mentoring role of reviewing becomes much more central to the informing process. To begin with, objective assessment may be almost impossible. Anyone who has served as a journal editor is aware of the extraordinary range of reactions a given article typically produces across reviewers. This is true for top-rated journals as well as for those lower in the rankings (e.g., Pfeffer, 2007, p. 1337). While this is generally explained as a variation in the quality of the reviews (and hence reviewers), where the domain is complex such variation may better be viewed as a virtually inevitable result of variation in client (reviewer) interpretations. Thus, where we can add greatest value to the informing process is not through culling manuscripts of insufficient quality through the reviewing process but rather by helping contributors increase the quality and resonance of their ideas prior to publishing them.

This philosophy of relying upon the review process as an important informing channel requires a departure from what would be considered normal in disciplines more oriented towards routine informing. As an example, it becomes much more important for reviewers to identify those aspects of a manuscript that resonate with them, rather than its deficiencies. The greatest change, however, comes with respect to the role of editor or associate editor. To ensure contributions reach their full potential, an intensive process of reciprocal informing between author(s) and editor needs to take place. In some cases, this may involve editors actually editing manuscripts to help authors communicate their ideas more clearly and, from time to time, even reframing those ideas. This, of course, is a much more demanding role than simply offering a simple thumbs up or thumbs down. But it is the role that is demanded by a non-routine informing system. It is through this channel that we will bring new participants into our endeavour and continue to enhance the understanding of those of us who are helping define the informing science field.

It may seem as if the philosophy I have just espoused represents an "anything goes" approach. This, however, is most definitely not the case. In fact, during my first month as Editor-in-Chief at *InformSciJ* I developed two email templates to send to authors who had just made new submissions. The first could be paraphrased "I'm sorry, but I'm returning your manuscript because I cannot see that it bears any relationship to informing". The second could be paraphrased as "I believe your manuscript has relevance to informing. But... I am not going to send it out for review until you revise it to explain what you think that relevance is". Of the first four submissions that came in, three received the first email and one received the second. This reflects my concern about another characteristic of non-routine informing: its vulnerability to misinforming.

Preventing Misinforming

As per Observation 17, a high potential for misinforming is inherent to non-routine informing systems. Based on what I have seen in this book, supplemented by my experiences writing for and editing *InformSciJ*, I see two particular types of misinformation as being particularly prevalent:

1. Misunderstandings as to the nature of informing science
2. Misunderstandings with respect to our terminology and how we apply the models that we are starting to develop.

As a non-routine informing system, the boundaries of informing science are likely to be somewhat amorphous. Nonetheless, there seems to be a growing consensus in the field, supported by many (but not all) of the chapters in this book, that it is best to limit our research to settings where human clients—as opposed to a technology clients, such as a CNC robot—are being informed. More dangerous to the field, in my opinion, is the danger that we become too closely aligned with one of our client disciplines (such as MIS or education) and, in process, risk losing our transdisciplinary flavor. There are certainly strong external forces that could drive us in that direction, since journal rankings for transdisciplinary endeavors are virtually unknown and many of our participants may be judged using such metrics. But, at least in the case of *InformSciJ*, I see the choice as being clear. We can become the world's premier journal on informing—a field yet to gain a lot of recognition—or we can become a second-choice journal in whatever field coopts us. In MIS, at least, there are already far too many of the latter.

Hopefully, this book will help us develop a consensus with respect to what informing science is about. With this chapter, however, I hope I have made it clear that such a consensus must not revolve around a single paradigm or perspective. Rather, it should help us identify those questions that are central to our field. A book, however, represents only a single step. We must continue to inform each other and those researchers currently outside of informing science regarding what we do. I see this process as central to our next decade.

The other area of misinforming highlighted by this book involves terminology. Quite candidly, I believe that we are shooting ourselves in the foot by refusing to come to a consensus on what we mean by common terms such as data and information. Over the course of editing the chapters in this book, I have noticed authors can become particularly intractable in this area. In most cases, they can point to strong support from their reference discipline, such as philosophy, that justifies their particular usage. Unfortunately, another author will present an equally compelling case from another reference discipline, such as computer science, justifying an entirely different usage of the term. Based on my own experiences studying task complexity (see Chapter 7), the inability to define terms or constructs consistently can eventually cause a discipline to view research relating to that construct unfavorably. Given the centrality of the terms involved, such a development would be a very bad thing for informing science.

It may well prove that researchers and practitioners in each discipline will use their own established terminology, regardless of any preference we state. This cannot be viewed as entirely bad, since the familiar terminology of a particular discipline may be the most effective way to communicate with clients in that discipline. What would be particularly useful in this circumstance would be something like a concordance over client disciplines of informing science. Each discipline would then make its assumptions and important distinctions explicit. For each term entry they should show near synonyms in other disciplines. Developing such a tool for communicating could make a valuable contribution to our research in the future.

Conclusions

When Eli Cohen and I were discussing the cover image to be used for the book, he proposed it be constructed around building blocks, the smallest unit of the typical foundation. I suggested another image might be even more appropriate: that of a farmer shovelling organic matter on to a compost heap. Foundation stones forever retain their original identify; shovelfuls of compost quickly become integrated with what is already in the pile. A stone foundation depends on uniformity of size and material; a compost heap accepts many different materials in many different shapes. Foundations support only that which is built upon them; compost is meant to be spread around. Foundations endure for long periods of time; the forces of nature cause compost heaps to shrink unless continually replenished. Thus, foundation stones can be seen as a metaphor for our search for the principles of routine informing. The compost heap is a metaphor for complex informing, particularly in an environment of technological innovation and globalization that continually changes the nature of informing system fitness. However, the image of the farmer shovelling piles of organic material could easily be misinterpreted by the readers. Then Eli came up with a brilliant design, a young plant (signifying order) growing out of soil (signifying chaos) held within human hands, signifying the central role that humans will always play in informing.

The central conclusion that I would like the reader to take away from this chapter is that routine and non-routine informing systems are very different and that informing science needs to be concerned with improving our understanding of both. If we become fixated on just one type of system, our shared understanding will naturally evolve into a form that makes informing science unattractive to many of our current client disciplines. Even more important, however, such a fixation will cause us to lose perspective on the full scope of the informing process. After all, non-routine informing systems frequently become routine just as the process of replacing a routine informing system with a different system invariably requires non-routine informing. To look at only one type of informing is to see only part of the whole.

As long as we retain and recognize the validity of the multiple perspectives that currently exist in our transdiscipline, we can become a source of insights that our client disciplines, on their own, cannot hope to match. I see that as the hope for the coming decade of informing science.

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Chapter 23

A Philosophy of Informing Science

Eli B. Cohen

Abstract

Informing Science is the transdiscipline that studies all issues in informing clients. In recent decades, advances in information technologies magnify the impact and importance of this transdiscipline on many fields of study. Yet transdisciplinary research conducted to date tends to be field-specific and not well informed by the works conducted in other fields that are also within this same transdiscipline.

This paper provides additional context and so updates the content of the Cohen 1999 paper, the seminal work on Informing Science that is Chapter 2 of this book. This paper describes the Informing Science Philosophy of conducting research that crosses disciplinary boundaries. It also points out the need for colleagues from the diverse disciplines, each dealing with issues in informing clients, to communicate with and learn from one another.

Introduction

The transdiscipline of Informing Science, as introduced by Cohen (1999), explores how best to inform clients using information technology. Thinking and researching in Informing Science has expanded in the last decade. The journal *Informing Science: an International Journal of an Emerging Transdiscipline* is in its twelve year of publication and the journal *Issues in Informing Science and Information Technology* is in its sixth. A Google search for the phrase "Informing Science" now brings up over 38,000 hits.

The evolving transdiscipline involves various reference disciplines including psychology, computer science, evolutionary biology, and linguistics. Disciplines that use Informing Science are diverse: included are education, government, business, public relations, and dozens more.

The essence of the Informing Science philosophy is the transfer of knowledge from one field to another: breaking down disciplinary boundaries that hinder the flow of knowledge.

This paper aims, first, to show the evolving importance of Informing Science. It also points out areas of research that need further exploration and the need for refinement of the Informing Science framework.

Informing through Metaphors

This paper makes use of a number of metaphors to describe and explain its points. This is nothing new. Goschler (2007) writes about how metaphors inform and impact scientific thinking. This use fits particularly well with the Informing Science philosophy that knowledge developed in and for one area of study often enlightens inquiry in other disciplines

The term "metaphor" can be used to mean several related things. Here we are following the linguistic (not grammatical) meaning as a method of applying existing knowledge of how things relate (cognition) to create an understanding of new situations. That is, it is a method that transfers ways of thinking and/or applies existing knowledge to new and different situations. (See Lakoff and Johnson, 1980, 1999, for a more detailed discussion of how linguists use the term "metaphor" and Schunk (2004) on its uses in education.)

Exploring with Lasers and Lanterns

The first metaphor to help us better understand the Informing Science philosophy is the laser beam and the lantern (adapted from Cohen, 2007b). As we know, a laser provides a highly focused, narrow beam of illumination that stretches to great distances. In contrast, the lantern, while it may provide the same amount of illumination in total, lights up a broad area. It is purposefully unfocused, and so its brightness diminishes exponentially at distances from the source.

The laser and the lantern each have its own qualities and uses. The lantern is best at enlightening interrelationships of nearby objects. For this reason we likely would choose a lantern for illumination if walking on a dark path through the wood. But if we wanted to look far into the dark woods, we likely would choose a laser or other highly focused beam of light.

There is no one single best source of illumination. Both lasers and lanterns have their uses.

We can apply this metaphor to research as conducted in traditional universities. When we do, we note a problem. Only "laser" research is fully rewarded on campuses. Here is what I mean by that. Traditional universities (in the US, anyway) are organized into colleges or schools. Each college is composed of various departments. Figure 1 pictorially shows such a silo organization.

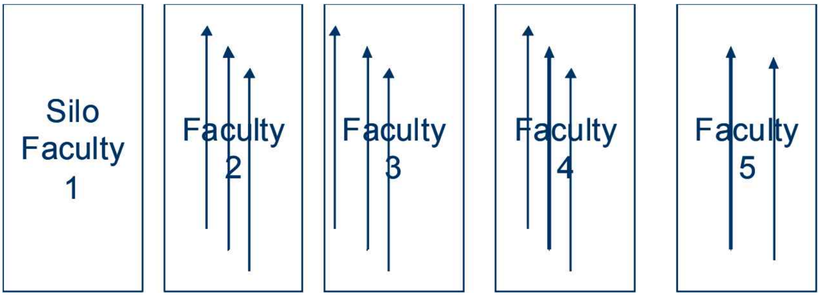

Figure 1. Laser research (shown by arrows) is narrow; lantern research is broad and often crosses disciplinary boundaries

Professors receive their rewards (paychecks and raises) based on their activities in support of their own department (and school). The most prized (and rewarded) research is conducted on topics specific to one's own department. Research conducted in other areas, even if in collaboration with colleagues from other faculties, is not viewed as valuable as research entirely within one's own department's field. (Indeed, graduate students may find it difficult to find a research advisor if their research is different than that already being conducted in the department.) Such prized research is "laser" research. It builds on and extends the narrow focus of research already considered legitimate.

Therefore, the traditional university structure leaves unrewarded "lantern" research that illumines fields that extend beyond one's own department. In this way, research addressing the so-called wicked problems of the world (Rittel & Webber, 1973) is left relatively unrewarded since these problems cross disciplinary boundaries. Yet for many, including me, they are the most interesting exactly because they defy simple, discipline-specific solutions.

Over Time, Disciplines Have Evolved

While it is true that traditional university departments (typically designed around one or a few disciplines) do get reorganized from time to time, such change typically is due to non-academic reasons (such as the need to rebalance workload or to reflect the capacity limits of the building that houses the department's offices). Separate from these administrative changes are more dramatic changes occurring to the actual disciplines within departments. Across the university, disciplines have evolved and are evolving in response to changes in technology, including information technology. Some disciplines change, some new ones are born, while still others slowly wither toward extinction.

We can track much of the source of this evolution to technological changes. Consider how newspaper and journal publishing has changed within our lifetimes in response to the web and print-on-demand technology, including home and office printers. Similarly, retail sales, including bookstores, are undergoing dramatic change. The world-wide web has enabled sales to remote customers but also brought competition from remote locations.

Even though disciplines have evolved to take advantage of advances in information technologies, outdated disciplinary biases remain as to what each field is and is not. The story/metaphor of the elephant and wise men helps us understand these biases.

Professors describing an elephant in various ways

An old story from India, told in various forms, relates how when blind men each touch a different part of an elephant (the tusk, leg, side, trunk, or tail), they each understand the elephant differently, each with complete confidence, but with only partial truth ("Blind men and an elephant," n.d.). So too it is with typical university field-based research. Our field's training and assumptions impose upon us as researchers a bias that blinds us to other elements of that which we are studying.

Like the elephant, reality is complex with many different elements, all of which are true but each of which is only part of the whole truth; therefore informing clients about reality is complex. To reduce this complexity, disciplinary fields focus on specific features and ignore or at least diminishing other features of reality. This bias in deciding which features are important and which are not is necessary, but it is bias. We can see only what we look at and focus upon (and not other things). (It is a human capacity limitation or fragility that is the source a bias. See Chapter 8 for a list of such biases.)

For this reason, when information science researchers view informing, they see only information science. When computer science professionals view informing, they too see it as but a part of their field. The same is true for information systems professionals, and so on. Their biases make it difficult for them to see that Informing Science is more than just what they study. Let us explore the idea further using the metaphor of the ugly duckling.

Ugly Duckling: Evolved Disciplines that Study Informing Science

Danish author Hans Christian Andersen wrote the tale *The Ugly Duckling* (Andersen, 1843/1949) about a cygnet (young swan) ostracized by ducklings because he was different. Cohen (1999) uses this metaphor to convey how Informing Science, while different from other disciplines, has a beauty of its own. It is not just an imperfect version of MIS, library science, or education, for example.

Indeed, many fields are confronted by problems in using information technology to inform their clients, including the following:

- MIS informs business clients,
- Library Science informs library patrons,
- Medicine informs medical workers and patients,
- Communications and Rhetoric inform the public,
- Government informs citizens,
- Education informs the student,
- and so on.

Because they are focused on their own field, when researchers in these fields look at Informing Science they tend to see it as just an imperfect way of viewing their own discipline. Yet, Informing Science is a tool to solve the problem shared by these fields: how best to inform clients. In this way it has a beauty of its own, as does the swan.

Same words, but different foci

Even though various fields claim "IS" as their own, they fail to realize that they are using the term to mean different things. The disagreement on the meaning of "IS" is due to cultural bias, that is the hidden assumptions that define which topics are interesting and acceptable for research.

- The focus of research for an "Information Scientist", that is from the school formerly known as Library Science, is the information seeker. (Kuhlthau, 1991)
- The focus of research in informatics and Management Information Systems is the information system (that it needs to create for the user).
- For the researcher from a technology school involved with informing clients, such as from computer science or applied computer science, the focus is the technology to provide a solution. No matter what the problem, technology is the solution.
- The focus for those involved in Intelligence (Military, Government, Business) is information gathering and analysis. Intelligence services includes credit reporting agencies

Same words, but different meanings

Even within the same field, in this instance Management Information Systems, researchers use the same words, but have different definitions. Evaristo and Karahanna (1997) note that IS research as conducted in North America is qualitatively different from IS research conducted in Europe, both in focus and in epistemology. The term is used to mean different things yet these researchers are from the same field!

Informing Science is the union of aspects of these disciplines, the aspects that relate to informing clients. Its purpose is to inform these disciplines. By union, I mean more than just summing all the work. There is synergy in bringing together researchers from diverse fields to bear on the common problem of how best to inform clients.

Informing Science as an Evolutionary Idea

As noted above, academic disciplines are evolving. Russian-American cybernetician Valentin Turchin (1977; Turchin & Joslyn, 1999) posits metasystem transition as a process by which organisms evolve. The author of this paper perceives that many disparate fields are evolving from separate entities into something greater, organized around common problems, such as the problem of how best to inform their client. More and more universities are recognizing this evolution by reorganizing apparently dissimilar departments into schools and colleges of information studies. This is a good first step.

As Gill (2008b) points out, the research of Stuart Kauffman (1993) in evolutionary biology concept of fitness space also relates to Informing Science. Indeed, one may speculate that the problem with university-department reward system of research can best be explained by the ground-breaking evolutionary genetic research on inbreeding by Wright (1932). Inbreeding promotes genetic defects.

Many of Today's Problems are Transdisciplinary in Nature

With apologies for stating the obvious, note that the reason that Informing Science and other transdisciplines are needed is that many of today's most interesting problems are transdisciplinary in nature. The current silo research focus is ill-equipped to deal with such problems. Grandon Gill (2008b) argues that many of the types of informing problem that we are attempting to address today involve achieving fit between components that are quite complex in their interdependencies. Understanding how fit is achieved when humans are involved may draw from a myriad of disciplines including, for example, psychology, communications, management, and computer science, as well as many other fields related to the specific task. Such problems often exhibit decomposable components as well as components that cannot be examined independently. Gill and Sincich (2008) further note that while the departmental approach to research may work reasonably well at exploring the decomposable elements—what they call the "low-hanging fruit"—it will invariable fail in its efforts to understand the non-decomposable elements. Even worse, it can easily be misled by statistical anomalies that result when a deep understanding of the processes is not present. Only a transdisciplinary approach, bringing together the expertise of all the disciplines relevant to a particular problem, offers any real hope of furthering our understanding. That is, for many problems, we need to examine the entire forest, not just this tree or that.

Informing Science: The Whole is Greater than the Sum of Its Parts

If we were to study only this tree and that tree, we would miss seeing the forest, for it is more than just trees. Forests also contain birds and animals and insects, vital for its well-being.

Likewise the elephant is more than a leg, trunk, tail, side, tusk, and such. It has parts that the blind men did not examine and they all interrelate. Similarly, informing too is more than the sums of its individual parts.

The late philosopher Stafford Beer pointed out that Informing Science is a transdiscipline. Philosopher Michael Scriven (2008) defines a transdiscipline as a discipline that serves many other disciplines as a tool (Figure 2). For example, modern statistics, developed to assist the study of agriculture or of mortality (depending on the source cited) is now used in the study of psychology, business, and countless other disciplines that employ experimentation.

Sentence Definition of Informing Science

Building on the work of Mason and Mitroff (1973), Cohen (1999 and Chapter 2) provided the following sentence definition of Informing Science:

The fields that comprise the transdiscipline of Informing Science

- provide their <u>clientele</u> with <u>information</u>
- in a <u>form</u>, <u>format</u>, and <u>schedule</u>
- that <u>maximizes its effectiveness</u>.

Understanding of each of the keywords of this sentence, such as clientele, information, form, format, schedule, effectiveness, can and should be expanded through research and so this sentence definition serves as a platform for research.

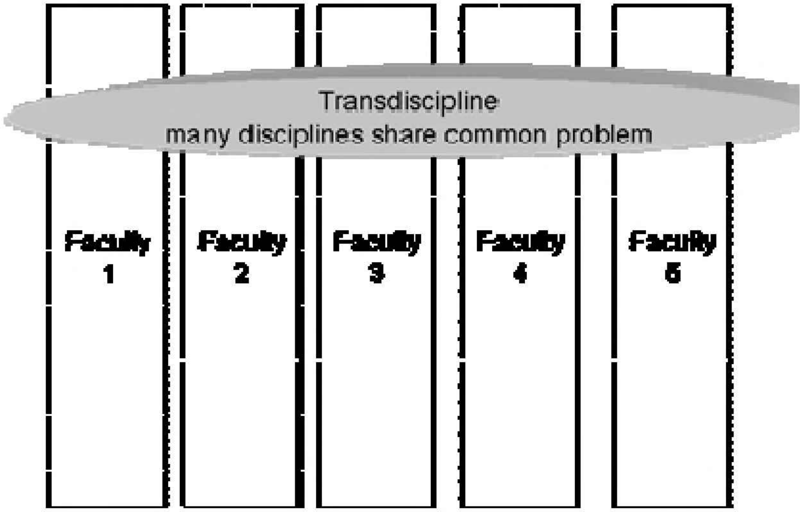

Figure 2. A transdiscipline is a coherent set of research topics that are shared by several distinct academic disciplines. (Universities are not yet well organized to reward transdisciplinary research.)

This sentence definition provides a simple means for describing Informing Science. It is easy to understand and to express. But its simplicity comes at the price of obscuring some of the more interesting complexities of Informing Science, such as the following:

1. Biological and psychological issues in how clients attend, perceive, and act on information provided,
2. The decision-making environment itself, including its sociology and politics,
3. Issues involving the media for communicating information,
4. Error, bias, misinformation, and disinformation in informing systems.

The point here is that a simple sentence definition is very practical and helpful in communicating but should not be used to limit the transdiscipline. The simple definition implies areas that need to be made more explicit through study. Hence, we should use more concrete frameworks in developing the transdiscipline.

Cohen's Informing Science Framework

In its most explicit, the Informing Science framework can be seen as both an extension and a special instance of the communications conduit model (or conduit metaphor), first proposed by Shannon and Weaver (1949) and adapted for use in linguistics by Reddy (1979). A simple rendering of that model (without the mathematics) is shown as Figure 3.

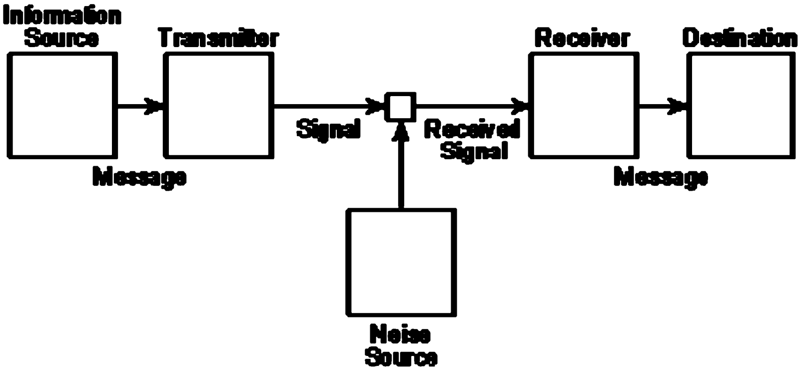

Figure 3. The "simple" presentation of the Shannon-Weaver (1949) Model for Communications. At the center of this model are the technologies involved in communications and their mathematical representations. Source: http://upload.wikiMEDIA.org/wikipedia/commons/f/f3/Shannon_communication_system.svg downloaded September 1, 2008. WikiMEDIA drawings are in the public domain.

The Informing Science framework is also a special instance in that it draws from T. D. Wilson's 1981 model of information seeking behavior (Wilson, 1981; see also Wilson, 1999 and Wilson, 2000). As Figure 4 shows, that model points out the layers of complexity and barriers in information seeking, as explained below.

What's new? The Informing Science framework can be seen as an extension of these models. The extensions include explicit understanding of the limitations, that is, the "fragility" of the informer, the channel (including encoding for transmission across media and resultant decoding, all in the presence of noise), and the information client. These fragilities include (but are not limited to) human limitations in perception and processing, biases due to prior knowledge,

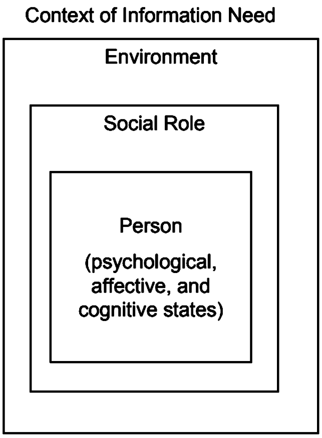

Figure 4: One component of T. D. Wilson's (1981) model of information seeking behavior.

skills, abilities, and information format preferences. Likewise, the information technology channel imposes its own set of limitations and biases.

To be clear, both Shannon and Weaver and Reddy understood that problems of communication are on three levels:

- *technical*: accuracy in relaying information
- *semantic*: correctness in conveying meaning
- *effectiveness*: the received meaning effects behavior

However, Shannon and Weaver focused their research on the technical level. Wilson focused his attention on semantic and effectiveness levels.

The revised, Informing Science conduit framework is seen as Figure 5. This figure expands the contextual environment of the informer, information transmission and receiving media, and receiver of information. It explicitly acknowledges that they exist within complex environments that greatly impact them. For example, the entity being informed is influenced by its own psychological and physiological fragilities and operates within task requirements (and anticipations), all of which exist within and are influenced by environmental context.

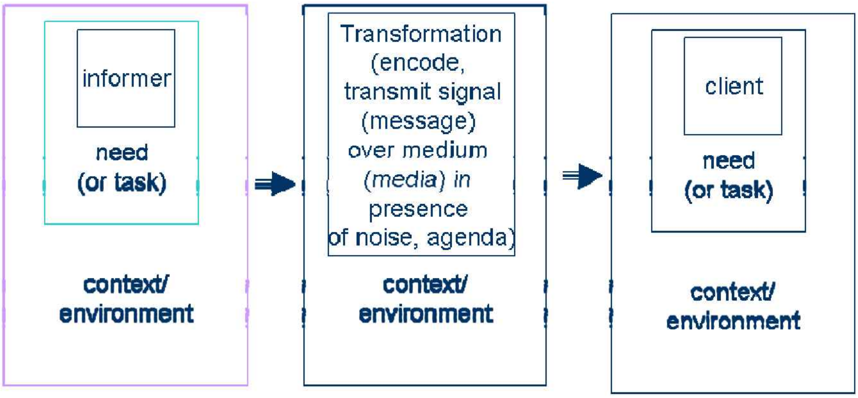

Figure 5. This rendering of the Informing Science framework includes the Shannon-Weaver model and the Wilson model, focusing the reader's attention on the components of informing clients, including the needs and human fragilities of both the informer and the client. It also points out that the medium or media exists within a context and environment.

It may be argued whether the need (or task) is within the context (environment) or visa versa. Likewise, T. D. Wilson's 1981 model places environment within the context and, for simplicity, the Informing Science framework combined these two elements. Regardless of these details (which need to be tested experimentally as well as logically), both frameworks agree that information needs of an individual are complex and are a function of context, environment, social or job role or task, and the individual's psychology.

Since both the informer and the client are influenced by human-related issues, they are best examined by those fields of study that deal with understanding cognitive, behavioral and social issues. Similarly, one might expect the technological concerns shown in the middle of the diagram to be studied by those who study technological issues.

The framework draws attention to the informer and the client, explicitly pointing out the need to study the environment and context of each, their tasks, and what we call their fragility. This paper uses the term fragility to refer to the cognitive limitations of human processing of information. A vast amount of literature already exists on the technological elements that must occur to get a message from one point to another across one or more media. This framework focuses attention on the other, less studied areas of Informing Science.

Is this framework complete? Of course not. It is useful as a step in developing a better framework and ultimately a model that has predictive value.

While this framework is helpful, it still leaves several important topics un-delineated. For example, what does it mean to "inform a client"? Is it merely providing information or does it involve more? For example, does the information provided need to influence behavior (such as decision-making behavior) for "informing" to have occurred. In a decision-making environment, does the information need to reduce risk? How can these things be measured?

Also, the conduit metaphor of Figure 3 has been criticized in that it contains tacit assumptions that the informer and client are "playing the same game," that is, both sender and receiver are using the same master metaphor. The same criticism need not apply to the framework in Figure 5.

This idea of "playing the same game", or context in which the information exists includes the concept of framing (Tversky & Kahneman, 1981). Tversky and Kahneman demonstrated over a multitude of experiments that the behavior of the "client" depends not only on the information transferred from the informer, but also on the context, or frame, in which the information is transferred. Figure 6 shows the relevant portions of Figure 5 that deal with framing. When

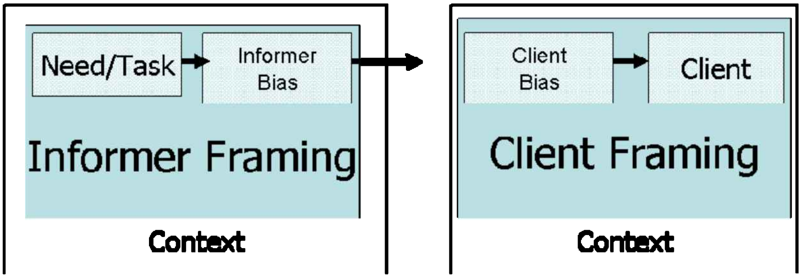

Figure 6. The Framing phenomenon can be viewed within the Informing Science framework as the way in which the informer creates the message in view of the informer's need or task and bias and the client interprets the message in terms of his/her own need or task and bias.

the sender initiates informing, s/he has a particular frame in mind. Similarly, the client selects (perhaps unconsciously) the interpretation frame. Informing breaks down when there are fundamental differences between the frames.

Lastly, it is very important to understand that the framework presented in Figure 5 is but one of many such frameworks proposed for the study of Informing Science. Many others appear on the pages of the journal Informing Science. This framework is meant to help guide research, not to define or limit the transdiscipline.

While the framework currently does address bias, it is not well suited in its present form to address the issues of misinforming and disinforming. By misinforming, I am referring to systems that by mistake provide incorrect or misleading information. Examples of misinforming systems abound. Anyone using an automobile routing GPS system knows this when the system occasionally routes the driver on the wrong course. Disinformation is the intentional providing the client with wrong information. A child who claims to the teacher that the dog ate his or her homework provides disinformation; military forces in wartime employ disinformation against the enemy.

Areas for Further Research

The Informing Science framework provides a basis for identifying areas that are likely to be important in future research. In general, each individual research activity is likely to emphasize on one of the four key elements of Figure 5: the informer, the client, the task or need driving the informing process or the channels through which informing takes place. At the same time, recognizing the system-driven nature of informing processes and given the transdisciplinary makeup of Informing Science, such research will also necessary consider the implications of its findings for the system as a whole. Let us now consider examples of topics drawn from each of the four areas. Again, these are only examples and are not meant to limit the transdiscipline and it development.

Informer-Focused Research: Bias, Misinformation, and Disinformation in Informing Systems

The assumption behind all the theories and practice as taught in university is that information systems produce information. Little if any attention is given to bias, misinformation, and disinformation in information systems. What little attention that is given typically is confined to computer crime and accounting.

Cohen (2000a, 2000b, 2007a) has addressed the issue, at least in rudimentary ways. Those papers assert that bias is inherent to all information systems due to the need to select which data to summarize, analyze, and report. Bias, misinformation, and disinformation are present, but not well researched or reported in information systems. Cohen's papers view (computerized) information systems as a subset of informing systems and point out that much attention has been given to bias, misinformation, and disinformation in their broader contexts of journalism (for example, "Fox News Channel controversies," n. d.; Hoffman & Wallach, 2007) and the military. Stahl (2006) provides a critical perspective on the differences among information, misinformation, and disinformation.

(Bias is also present in the channel and in the client. The point here is to recognize bias in the informer.)

Client-Focused Research: Cognitive and Physiological Elements of Informing

Another area in which the framework needs development is in the explication of the cognitive and physiological elements of informing. As alluded to above, it is obvious that a full understanding of informing systems is beyond the scope of any one field. Those whose backgrounds are in building computer system are unlikely to understand fully the behavioral issues involved in informing people. Indeed, recent research findings indicate that we cannot blindly accept the assumption that clients behave rationally. Cognitive psychologists demonstrate that people have cognitive limitation (for example, Ariely, 2008). Brain scientists find neurological, chemical, and hormonal contributions to behavior and decision making (Burton, 2008; see also Levitan, 2006). Social psychologists and sociologists have contributions to add to the context in which decision making takes place (for examples, see Brafman & Brafman, 2008; Gladwell, 2002, 2005). Even economists contribute to understanding how people make decisions (for example, see Hartford, 2008). Therefore, this paper suggests that Informing Science includes the psychological, sociological, and physiological contexts in which people receive and process information. We will call this intersection of cognitive science with issues of informing ***cognitive informatics*** and hope that giving name to it will encourage additional research into the field.

Task/Need Focused Research: Complex versus Routine Informing

Gill and colleagues describe in detail how the presence of complexity can dramatically impact the nature of the process required to achieve effective informing (see Chapters 1, 7, and 22). Where tasks or needs are relatively routine and unchanging over time, we can expect that well-tuned informing systems can be designed to achieve efficient informing. A useful means of looking at these systems is in terms of three levels: 1) the informing instance level, where actual informing takes place, 2) the instance-creation level, where new informing instances are created, and 3) the design level, where general patterns for informing are established (see Chapter 2). As complexity grows, however, distinctions between levels are likely to blur and new patterns of informing and informing system evolution are likely to be required. Because the problems of dynamic complexity often fall outside the domains of existing disciplines (i.e., highly complex informing often falls outside the domain that is possible with existing information technologies, education typically does not study communicating content that is non-routine to both informer and client), it represents an important opportunity for the Informing Science field.

Channel-Focused Research: Informing Networks

Figures 5 and 6 convey the impression that informing takes place between a single informer and a single client through a single channel. In practice, however, senders and clients can both be collections of agents—often heterogeneous in key characteristics (e.g., motivation and prior knowledge)—and a variety of channels may be employed. To date, a great deal of research has been conducted related to the impact of heterogeneity on informing (e.g., Gladwell, 2002; Rogers, 2003). In addition, an exciting stream of research now focuses on how informing networks emerge and behave (e.g., Watts, 2003; Barabasi, 2003). Important discoveries remain to be made regarding how such networks are impacted by other characteristics of the informing context, such as the underlying task/need driving the informing process and how informer/client characteristics impact the process and its evolution. Here, once again, the transdisciplinary nature of Informing Science places the field in an ideal position to make important contributions in these areas.

Challenges to Research

There are a number of challenges to this transdisciplinary research, most of which are pragmatic in nature. These challenges include the need to change the reward structure of the traditional university and the need for opportunities to learn from the work, research, and needs of colleagues in other fields. The following are some steps that have been taken to meet these challenges and some that still taking.

Need for Journal

Research is unlikely to be conducted if the results would have no outlet for dissemination. After all, university's researchers are rewarded more for research that is published than for unpublished research. This could be a problem given the transdisciplinary nature of the research and the missions of legacy journals.

Journals typically limit what articles they will accept and publish according to their mission. The reader may see the problem here. Journals publish papers only within their scope; legacy journals follow the same disciplinary framework that has so successfully kept academicians in government, medicine, business, and the military from learning one from the other.

Therefore, there was a need for a transdisciplinary field of inquiry dedicated to the Informing Science to disseminate relevant research findings. Other transdisciplines have employed a similar approach. For example, the transdiscipline of statistics has numerous journals; in fact, statistics education alone has at least five journals devoted to the topic (Journal of Statistics Education, n.d.).

Need for Conference

Face-to-face interpersonal communications is required (or at least highly desirable) to build trust (Guadagno & Cialdini, 2007). Trust is necessary in any collaborative research, but particularly so with transdisciplinary research. It may require working with colleagues from other locations and countries, but also from other disciplines and, consequently, using epistemologies new to the researcher. Can such research be encouraged and promoted? The organizers of the Informing Science Conference (http://InSITE.nu) thought so and therefore hold an annual conference that not only presents research from diverse fields but specifically fosters trust-building interactions through shared dining and similar networking opportunities and activities.

A second reason for face-to-face meetings with colleagues from different fields is to make tacit knowledge explicit (Polanyi, 1997). As noted above, even colleagues in the same field (but from different backgrounds) commonly use the same words to mean different things.

Researchers Teaching Teachers Research; Teachers Teaching Researchers Teaching

An informal analysis of the articles appearing in transdisciplinary journals and the Informing Science conference mentioned above provides ample illustration to the benefits of researchers in one field teaching researchers trained in different fields about their own research methods and epistemologies. For example, a single article may draw upon the research traditions of philosophy, information systems, education and pedagogical science, and sociology, to name of few. New areas of research are being explored, perhaps because there is now a place for disseminating knowledge developed through this research. That is, even with researchers sequestered in their own academic silos, the Informing Science journal and its conference allows and encourages them to research together and learn from one another on common areas of interest.

Reward Structure

The typical traditional university does not have a reward structure to encourage research toward solving wicked and other pressing trandisciplinary problems. What is needed is for the university to recognize and reward the reunification of knowledge (overcoming artificial barriers imposed by administrative departments). Unfortunately, in most instances cross-disciplinary research is not rewarded as much discipline-specific research.

One solution to this problem is to reward generalists by recognizing lantern research as a specialty. In medicine, this was done by providing general practitioners with their own specialty, Internal (or Family) Medicine.

Summary of Philosophy

In summary, the Informing Science philosophy is that broad, transdisciplinary research is needed to understand how best to use technology to inform clients. Because many disciplines have evolved due to changes to technology, they need a better understanding of this transdiscipline. Yet, these disciplines have in the past been reinventing the wheel, unaware that colleagues from other disciplines are already working on the same problem. The Informing Science philosophy is to break down barriers that limit the exploration of this important topic.

Much work already has done in diverse fields, and colleagues need to benefit from cross-fertilization of their disciplines with others. The complex phenomenon of informing clients is best studied through diverse epistemologies so as to reduce disciplinary bias.

All the blind men reported their research with complete truth and accuracy, yet individually they understood very little of the elephant.

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Index

A

AACSB, 401
academic informing systems, 27
acceptance level, 332
acceptance of information, 331
accretion, 251
accumulators, 217
actionable datum, 308
actionable factors, 312
actionably credible, 312
adaptability, 371, 749
adaptation, 755
affect, 267
affinity, 621
agency theory, 211
AIS, 32
altruistic goals, 210
anchoring effects, 258
anger, 269
anomalies, 198
anticipated feelings, 273
antipathy, 621
applied research, 28
approach goals, 204
area of focus, 176
Argyris, 440, 488
Aristotle, 291
arousal, 261
arousal motivation, 263
associative learning stage, 180
assumed decomposability, 391
asymmetry, 324
attendance to channel, 752
attention filter, 249
attraction effect, 223
attractive theory, 386
authentic group-work contexts, 664
autonomous learning stage, 180
availability of information, 253
avoidance goals, 204

B

Bateson, 439, 465, 481, 485, 489, 492
Batterymarch Financial Management, 751
bauxite mine
  informing system for, 503
Bednar, 459, 462, 472, 488
bias, 309
bi-valued logic, 491
boredom, 264
boundaries of informing, 66, 309
boundaries of informing science, 764
bounded rationality, 199, 299, 320
bricolage, 483, 484
broadcast mission, 580
broadcasting business and general communication model, 582
broadcasting business model, 580
Brunsson, 489, 491
Bryce Canyon, 756
builders, 396
building new theory, 396
business processes, 297

C

capstone task, 646
cartesian split, 469
case research, 402
change-equilibrium model, 14
changes, 303
channel capabilities, 250
chaos, 750
chaotic landscape, 361
CHAT. See cultural historical activity theory
cheating, 274
Checkland, 462, 466, 476
choice strategies, 255
choice uncertainty, 294, 299
choices, 298, 299
Churchman, 483

Ciborra, 476, 483
circling of realities, 474
circular chains of determination, 414, 417
citation analysis, 36
CKB. See collaborative knowledge building
clan organization, 542, 549, 564, 566
classes of task complexity, 174
classic utility model, 199
client, 378
client expertise, 328, 331
client filters, 753
client roles, 746
client-controlled design, 467
client-led design, 466
clients for informing science, 41
client-to-client, 744
client-to-client informing, 245, 275
client-to-client resonance, 275
closed cause-effect chains, 417
cockroaches, 242
co-creation, 467
co-evolution, 370
co-evolving systems, 758
coffee, 400
cognitive and physiological elements of informing, 781
cognitive biases, 245, 747
cognitive informatics, 782
cognitive learning stage, 180
cognitive preferences, 379
collaborative knowledge building, 661, 663
collaborative reflection. See collaborative reflective discourse
collaborative reflective discourse, 671, 685, 689, 690
commodities, 225
communication model, 13
communication skills, 643
compact theories, 758
compactness, 372
competing senders, 23
complex adaptive systems, 47
complex informing system, 739
complex informing system., 459
complex systems, 47
complexity, 377, 380, 414
component complexity, 165
components of decision-making situations, 303
compound metric of quality, 310
compromise effect, 223, 747
computer data, 296
computer processed and stored data values, 296
concepts, 301
concrete biological goals, 208
conditions for effective informing resonance, 65
conduit models, 745
confirmation bias, 253
conflicting interdependence, 165
connectionist, 218
connectors, 277
content, 584
content analysis, 724
context, 621
contextual dependency, 473, 488
contextual inquiry, 472, 484, 487, 495
contingency provision, 294
continuous aiming, 241
contradictions, 665, 680
control, 261
control motivation, 266
cooperative principle, 629
co-opting a channel, 745
coordinative complexity, 165
credibility, 328
criterion, 298
critical mass, 276
critical perspective, 742
critical systemic thinking, 459, 486, 496
cultural historical activity theory, 662, 675
culturally advanced activity, 666, 680
cyberdating, 619
cybernetics, 459

D

daily news, 578

data, 295, 302
data and information, 764
data and information processing, 297
data-information-knowledge hierarchy, 148
datum, 305
decision makers, 298
decision-situation specification matrix, 303
decomposability, 361
decomposable, 757
decomposable fitness landscape, 386
decomposable landscapes, 370
dedicated channels, 745
defensive routines, 488, 489, 491
define the boundaries and scope of informing, 308
degradation of decision situations, 313
degree of acceptance, 342
degree of information asymmetry, 333
delivery system, 15, 22, 60, 139, 378
dependant variables, 298, 320
Dervin, 474
design, 744
design specification, 166
desirability bias, 252
desire to exercise control, 216
detection of disinformation, 634
detector-accumulator model, 217
detectors, 217
deutero-learning, 459
Dewey, 292
dichotomy of the available and not-yet-available factors, 314
differences between "hard" sciences and the arts, 376
diffusion, 240, 275
direct factors, 311
disciplinary and institutional leadership clients, 45
disciplinary informing system, 27
disciplinary silos, 231, 406
disciplines
  evolution of, 770
discommunication, 310
discounting, 226
discretion, 163
discussion group trolling, 269
disinformation, 309, 619, 621, 781
  and reception, 627
  in cyberdating, 632
distal goals, 204
distance education, 113
distance learning, 44
  web-based, 119
distortion, 244
distractibility, 264
diversity, 750
diversity network, 492
doctoral programs, 33
double bind, 485, 489, 493
double helix, 248, 459, 464, 465, 485, 495
drive for control, 382
drive to acquire, 209
drive to bond, 209
drive to defend, 209
drive to learn, 209
drive to reduce uncertainty, 209
drives, 267
dynamic complexity, 165
dynamic fitness landscapes, 369
dysfunctional family, 492

E

early adopters, 276
Easterlin Paradox, 227
economic men, 418
economics, 197
economy, 293
edge of order and chaos, 372
education, 657
effective communication, 310
effectively usable factors, 312
efficiency, 371, 749
efficiently usable factor, 89
egoistic goals, 210
Ehn, 466, 484
Einstein, 292, 304
e-learning, 113
elephant and professors, 770
elimination by aspects, 255
emoticons, 625

emotional anchoring, 272
emotional framing, 271
emotional impact on choice strategies, 272
emotional intelligence, 493
emotional labor, 275
emotions, 267
emotions and information processing, 268
emotions versus feelings, 267
empiricism, 709, 718
enhanced memory of emotionally significant events, 268
environment, 621
  of informing, 15
environmental turbulence, 752
equal weight heuristic, 255
ergo-transformation processes, 297
error term, 758
escalating commitment effect, 262
ethically and/or efficiently usable factors, 312
ethically usable factor, 89
ethics, 89, 293
ETHICS - Effective Technical and Human Implementation of Computer supported Systems, 466
evaluate risk of misinforming, 329
evolutionary approach to IS, 11
evolutionary biology, 773
evolutionary idea, 773
expanders, 396
expected utility, 200
experiment, 375
expert system, 184, 266
external clients, 31
external goals, 204
extra-textual cues, 630

F

face-to-face communication, 623
face-to-face interaction., 638
factors
  in form, 295
  in substance, 295
factors in waiting, 312
failure of transmission, 323
failure to attend, 323
failure to impact, 323
failure to inform practice, 403
feature detectors, 217
feelings, 267
filter model, 747
filters, 245
fit, 357
fitness continuum from science to art, 372
fitness function, 358
fitness landscape, 185, 357
fitness of an art work, 375
four-valued logic, 491
frame of reference, 298, 319
  definition, 319
framing, 205, 220, 225, 257, 779
frequency of good and bad features, 256
Friis, 467
fundamental desires, 209

G

gain-loss asymmetry, 205, 221
Galtung, 427
game theory, 493
garlic acceptance model, 392
general-purpose agents, 221
genetic algorithms, 368
globalization, 385
goal allocation, 211
goal attendance, 214
goal attention levels, 215
goal commitment, 214, 216
goal difficulty, 206
goal fitness operator, 246
goal frames, 221
goal proximity effect, 205
goal setting literature, 205
goal setting theory, 204
goal space, 246
goal specificity, 204
goal-based utility decision model, 207
goals, 162
goals vs. needs, 206
graduate skills

communication skills & problem solving, 643
graph structure, 297
Grice's cooperative principle, 629
group decision support system, 744
group presentation assignment, 755
Gunfire at Sea, 240

H

Hay, 492
Heidegger, 478, 494
helical design processes, 743
hermeneutic circle, 475, 496
hermeneutic dialectics, 469, 475, 759
hermeneutically-informed approaches, 459, 464, 484, 486, 495
high reliability organizations (HROs)., 422
historical and organizational context, 754
history, 758
history of science, 718
homogeneous clients, 23
hub node, 279
human activity system, 425, 462
human clients, 764
hypocrisy, 489

I

identifying peaks, 398
illusions of control, 266
immediacy effect, 226
immediacy of feedback, 623
inbreeding, 773
incremental improvements in performance, 747
incremental informing, 747
independent variables, 298, 319
indirect factors, 311
indirectly useful factors, 312
individual emergence, 494
infinite dance of changing coalitions, 492
infoculture, 530, 549
infological equation, 460, 477
infopolitics, 525, 543
informal communication, 549, 561
informal delivery system, 570
information, 287, 441
  quality and use-related requirements, 68
information asymmetry, 325
information authentication, 624
information biases, 245
information culture, 521
information management, 526, 547, 555, 558, 560, 567, 570
information overload, 264
information politics, 521
information processing, 159
information sciences, 328
information technology, 385
information view of organization, 521
information, and informing are physical, 288
informational misbalance, 326
informational transaction, 620
informer-client interactions, 620
informing, 297
  cognitive and physiological elements, 781
  effect on operations, 78
  versus information systems, 420
informing entities, 60
informing environment, 22, 137
informing for operations, 288
informing instance, 25, 744
informing networks, 782
informing process, 323, 326
informing science, 22, 461, 767
  as a new discipline, 16
  definitions, 12, 774
  origins of, 7
  philosophy, 785
  transdiscipline, 760
Informing Science - The International Journal of an Emerging Transdiscipline, 2, 21, 26, 764
informing science framework, 13, 22, 59, 98, 137, 413, 485, 579, 620, 648, 661, 672, 776

Informing Science Institute, 2, 21, 46
informing system, 570
characteristics, 743
informing system design, 25
informing system fitness landscape, 377
informing systems
for operations, 57
teleological view, 59
use and redesign, 411
informing view of organization, 521
inhibiting links, 213
innovators, 276
inquiring system, 483
InSITE, 21
instance creation, 25, 744
institutional informing system, 28
instructional design, 114
interaction term, 363
interactive activation model, 219
interdependence, 363
interdisciplinary context of informing, 309
interference, 265, 268
internal clients, 28
internal goals, 204
internet dating and matching services, 619
interrelated goals, 747
interrelatedness, 25, 679
intrinsic motivation, 159, 260
invariances, 428
Irish potato famine, 750
IS1, 462, 466, 467
IS2, 462, 466

J

job design and enrichment, 380

K

Kauffman's NK Model, 362
Kauffman's NK model, 185
key informants, 276
knowing, 492
knowledge, 148, 287, 299
methodological, 710
knowledge artefacts, 662
knowledge compilation, 247
knowledge creation metaphor of learning, 667
knowledge management, 537, 549, 560, 566, 569
knowledge workers, 23

L

lack of decomposability, 367
laggards, 276
Langefors, 460, 467, 475, 477
language variety, 624
laser beam, 768
Law of Abandoned Expertise, 262
Law of Limited Visibility, 262
Law of the Few, 277
leaky accumulator model, 219
learner-centred learning, 657
learning, 179, 216
learning architecture of the utility function, 215
learning by analogy, 257
learning goals, 204
learning stages, 180
learning style, 382
levels of abstraction, 24
lexicographic heuristic, 255
life cycle of the content, 584
likelihood of achieving goal, 214
limited attention, 207
Lindblom, 483
local fitness peak, 368
logical empiricism, 470, 758
long term self interest, 268
longitudinal investigation, 398
low budget delivery system, 578
low budget multimedia technologies, 579
low hanging fruit, 392

M

majority of confirming dimensions, 256
managers, 298, 319

many-to-many informing process, 341
marginal utility, 229
Maslow's hierarchy, 209
mass media, 276
materiality
  definition, 320
  of an entity, 299
  of properties, 71
  related to use of factors, 313
materially significant, 299
materially significant entities, 321
Maturana and Varela, 459
mavens, 277
maxim of manner, 629
meaning shaping, 474
meaningful factor, 322
measurability, 299, 320
measure, 324
media characteristics of cyber space, 619
media richness, 250
medium as the message, 622
mental model, 251
mentorship, 762
message genres, 562
metaphors, 768
metascience, 469
metasystem transition, 773
methodological knowledge, 710
migration towards structure, 751
mirror neurons, 211
MIS, 296
  program capstone, 749
  research discipline, 750
MIS case study, 25
MIS concpets, 739
MIS discipline, 21, 761
MIS program enrollments, 33
MIS textbooks, 58
miscommunication, 310
misinformation, 309, 440, 621, 781
  and intention, 626
  and situational desirability, 628
  in cyberdating, 626
misinforming, 323
  preventing, 764
misleading knowledge, 323
MISQ, 32
model of informing for operations, 298
model of production and post-production, 589
money and utility, 224
moods, 267
motivation, 204, 379
motivation filter, 250
motivational conflicts, 244
Mrs. Fields Cookies, 751
muddling through, 483
multi-attribute interdependency, 203
multi-attribute utility, 200
multiple clients, 24, 28
multiple communications pathways, 23
multiple cues, 624
multiple end states, 165
multiple informing systems, 23
multiple linear regression analysis, 387
multiple paths, 165
multiple peaks, 750
multiple perspectives, 766
multiple regression, 757
Mumford, 466, 477

N

natural evolving processes, 297
natural inert processes, 297
needs, 205
neoclassical economic theory, 197
neoclassical utility functions, 211
network for news exchange, 577
news branch office, 610
news package, 578
news production process, 578, 587
Nietzsche, 291, 304
Nissen, 461, 466, 475, 476
non-routine factors, 296, 301
non-routine information, 296

O

objective characteristics perspective, 173

objective complexity, 165
objective task complexity, 377
observed criteria for ruggedness, 393
one-to-many informing process, 336
one-to-one informing process, 334
online anonymity, 638
operational materiality, 303
operational meaning, 303, 312
operational significant materiality, 312
operationally complete, 91, 312
operationally irrelevant, 300
operationally meaningful information, 305
operationally on-site available, 312
operationally recognized, 312
operationally relevant, 312, 321
operationally timely available, 312
operations, 287, 295
operator space, 246
opinion leaders, 276
optimism, 252
order, 750
ordering of quality requirements, 311
orders of learning, 472, 481, 485, 488
organizational context, 754
organizational culture, 521, 530, 532, 549, 574
organizational memory, 537, 568
organizational politics, 521, 524, 525, 528, 538
organizationally situated systems, 746
orientee, 437
orienter, 437
outcome, 303
outcome bias, 252
overconfidence, 262
overlap of teaching and research interests, 34

P

package contribution methodology, 605
package distribution methodology, 606
pain, 267
paraconsistent logic, 491
paradigms, 263
paradox, 468, 492
paralinguistic features of conversation, 625
partially ordered, 311
participant opinions, 399
participatory design, 466
peaks, 361
Peirce, 293
perfect communication, 310
perfect rationality, 299
performance, 261
performance goals, 204
performer dependence, 174
personal context, 621
personal focus, 625
perspectives, 450
persuaders, 277
phenomenological perspectives, 496
philosophical doubt, 465, 472, 473, 476
philosophy of informing science, 785
philosophy of science, 712
physical approach, 289
Piaget, 437
planning and goals, 209
point of reference, 319
political constraints, 593
postulate of teleological perspectivism and relativity of assessments, 304
power law, 279
power of context, 277
practitioner clients, 31
practitioner problem space, 247
praxiology, 293
praxis, 248
predefined slots, 747
preference reversal, 225
preferred worlds, 428
pre-knowledge, 460, 472, 477
prescribed activities, 162, 747
presentation of self, 631
prestige, 402
pre-understanding, 474, 475
preventing misinforming, 764

prevention of irrational choices, 320
priming, 270
principia
impact on research, 314
principia of informing, 306
prior knowledge, 379
prior mental models, 243
problem based learning, 645
problem solving strategies, 163
problem space, 162, 246
processes, 296
processes by design, 297
procrastination, 273
prominent factors, 621
properties of the message, 331
proximal goals, 204
punctuated equilibrium, 369
pure research, 28
purpose, 319
purpose as point of reference, 291
purpose-focused activity, 747
purpose-focused framework, 67

Q

qualifiers, 396
quality assurance, 296
quality of information
measuring, 73
quality of message, 328
quality problems inherent to informing, 309
quantify the risk of misinforming, 329
quantum nature of information, 305
quantum nature of information and informing, 307

R

Radnitzky, 469
ranking organizations, 31
rational and rule following choices, 320
rational budgeting approach, 30
rationality, 293, 483
reality, 295, 757
real-life project, 645
receiver, 327
recency effect, 253
recipe fitness, 359
reciprocal informing, 643, 763
reciprocal learning, 644
recognition heuristic, 254
refereed journal articles, 761
reflection-in-action, 682
reflective competence, 486
reflective conceptual artefact, 682
reflective thinking, 663, 671, 688
refusal to be informed, 274
relevance, 239
relevant operational variable, 321
reliability, 373
reporters, 396
repositories of learning objects, 762
representations of changes and/or distinctions, 300
representativeness, 252
requirements shaping, 472
research challenges, 783
research cultism, 722
research guiding interests:, 425
research methodology, 711, 718, 727
researcher interpretation, 394
researcher objectivity, 758
resistance, 244
resonance, 42, 239
resonant communications channels, 42
resources, 295
restrictive environment, 577
restructuring, 252, 257
review and editorial processes, 762
reward structure, 784
rich media, 624
rigor, 239
risk
impact on utility, 200
of a client, 334
risk and time preference filter, 250
risk and time preferences, 256
risk biases, 246
risk of misinforming, 323, 324, 326, 332
robustness, 373, 753

routine communicated information, 296
routine data, 300
routine factors, 296
routine information, 300
routine informing, 230
routine management, 298
routine vs. non-routine behaviors, 750
routine vs. non-routine objectives, 746
routine vs. non-routine research, 754
routine vs. non-routine structure, 743
rugged fitness landscape, 185, 357
ruggedness, 361

S

Santa Fe Institute, 48
satisficing, 255
scale-free model, 278
schema creation, 252, 257
schema evolution, 252, 254
scholarship of teaching, 28
scholarship of teaching research, 36
Schopenhauer, 290
Schutz, 465, 472
science, 288
scientific knowledge – hard-science, 300
Second Life, 762
self-disclosure, 631, 635
sender, 326, 378
sender's awareness of client, 380
sense-making, 459, 465, 472, 474, 475, 489, 493, 496
serving system, 476
Shannon and Weaver, 13, 776
similarity effect, 223
simplified production chain, 588
single client resonance model, 248
single outcome calculation, 262
situation-specific operational meaning, 322
situation-specific primary necessary use requirements, 312
situation-specifically operationally relevant, 321
small world model, 278
social constructivism, 674
social context, 746, 760
social cues, 624
social networking sites, 762
social self-regulation theory, 227
social visceral factors, 274
societal environment, 621
socio-technical, 466, 482
soft systems methodology, 466
software development, 643
spurious significances, 757
SST framework. *See* strategic systemic thinking framework
stages in a communication process, 326
state space, 246
state transition triggered, 308
statistical analyses of rugged landscapes, 388
steps in the staircase of human cognition, 301
stickiness factor, 277
Stowell, 466
strategic management, 298
strategic systemic thinking, 491
strategic systemic thinking framework, 496
strategic systemic thinking framework, 484, 487
structural complexity, 246, 740
structural complexity model, 252, 258
student clients, 33
subjective perceptions, 267
success in informing, 329
success of informing process, 324
sufficient reason to act, 290
survivability, 359
synchronous electronic communication, 623
system boundaries, 744
system to be served, 476
systems science, 459
systems thinking, 459

T

tactical management, 298
task, 162
task completion environment, 22
task complexity, 159, 164
    and alternative performers, 182
    and external tools, 183
    and shared tasks, 167
    classes, 178
    constructs, 169
    definitions, 168
task transformation, 179
task-completion system, 15, 139
task-person interaction perspective, 172
task-related goals, 230
tasks transformed by IT, 167
taxonomy of quality requirements, 311
team organization, 557
teamwork, 646
technical constraint, 594
technology clients, 764
technology-induced changes, 25
teleological approach to informing, 291
teleological perspective
    on informing, 58
teleological perspectivism and relativity, 306
temporal anomalies, 200
testers, 396
testing existing theory, 396
theory development, 391
therapeutic catalyst, 487, 492, 496
threshold of significance, 299
time preferences, 200, 226
Tipping Point, 277
total task complexity, 165
Tower of Hanoi, 257
transaction cost economics, 211
transcontextuality, 490
transdisciplinary nature of informing, 309
transdiscipline, 411, 760
    definition, 774
trans-formation, 621
triangulation, 394
trust, 619, 624, 633
    between strangers, 628
    first level, 630
    levels of, 637
    loss of, 629
    sense of, 631
    source of, 628
trust in truthfulness, 630
tuning, 252, 254
two-to-one informing process, 337

U

ugly duckling, 7, 771
ugly theory, 394
Ulrich, 474, 486
ultimate purpose of informing, 309
uncertain usability of factors, 313
uncertainty, 165
uncertainty biases, 246
unexpected informing, 264
unfamiliar choices, 218
university ranking, 365
usability, 115, 465, 476, 481, 494
    attributes, 115
    of e-learning courseware, 113
    properties, 117
    research, 117
usability of a factor, 89
usability properties, 748
use requirements, 82
usefulness, 465, 467, 476, 481, 494
user involvement in design, 744
utility, 197, 260
utility decision model, 207
utility function, 303
utility model, 199
utility theory, 198

V

valence, 215
valid information, 310
value chain, 580
value of information, 323
visceral factors, 230, 267, 269
visceral factors filter, 250

W

warranty, 343
Weick, 489
well defined tasks, 749
well-ordered, 311
Weltanschauungen, 466
wicked problems, 769
Wikipedia, 762
will, 290
Wilson, T.D., 776
wisdom, 301
wishful thinking, 252
Wittgenstein, 446
word of mouth, 24
work system, 466
workflow, 589
workstation, 603
worldview, 466

X

XCON, 182

Z

Zing groupware, 674, 706

What is this book entitled *Foundations of Informing Science* all about? This is not a simple question and has no a simple answer. Informing Science was first theorized but a decade ago and has undergone continual development since its birth.

In its 23 chapters, this book provides a range of answers. Informing Science is arguably the most important new theory of this decade.

T. Grandon Gill is the current Editor-in-Chief of the journal *Informing Science: the International Journal of an Emerging Transdiscipline*. Eli Cohen is its founding editor. This book's editors and the authors revised their previously published papers to create this book. It formalizes the ongoing debate on the nature of informing that nurtures and fertilizes the emerging transdiscipline.

This is a must-read book for students and professors alike.

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