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DEPARTMENT OF INFORMATION SYSTEMS

INTRODUCTION TO KNOWLEDGE MANAGEMENT

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Contents

CHAPTER ONE
THE NATURE OF KNOWLEDGE

1.1. Introduction to knowledge: What is Knowledge?

"Knowledge" is quite distinct from "data" and "information," although the three terms are sometimes used interchangeably. However, they are quite distinct in nature.

Data represents unorganized and unprocessed facts. That is r*aw numbers, images, words, and sounds, derived from observations or measurements.*

Data

Usually data is static in nature.

It can represent a set of discrete facts about events.

- An organization sometimes has to decide on the nature and volume of data that is required for creating the necessary information.
- Data in itself has no meaning; it is the raw material for **information.**

What is Information?

- Information is processed data, it is a subset of data, only including those data that possess context, relevance and purpose and it involves manipulation of raw data

Information

- Is data with a meaning assigned to it and it is organized for some purpose.

  Example: raw data from survey analyzed to produce structured results
- Information can be considered as an aggregation of data (processed data) which makes decision making easier. It is the raw material for knowledge.

Knowledge

- Means to analyze/ understand information/data, belief about causality of events/actions, provides the basis to guide meaningful action and thought.
- Broader, deeper, richer than information
- Knowledge is a basis for making decisions
- A combination of information, instincts, rules, ideas, procedures and experience that guide actions and decisions.

•For example, getting a temperature reading of the climate outside on one day is meaningless without other inf ormation to make a comparison. Once a database is created, it becomes information because comparisons can be made. In terms of knowledge management, knowledge is information that is in context, producing an actio nable understanding.

- Back to our temperature scenario, when the temperature information is placed in context with say agriculture, then knowledge is created. For example, knowing that if temperatures fall below a certain point in January they tend to last for about a week. Orange farmers in Florida must determine if they are going to harvest early or take other precautions like heating the orchard. The decision will be based on how lon g oranges can withstand cold conditions at a certain temperature.

Knowledge can be defined as the ``*understanding obtained through the process of experience or appropriate study*. ''Knowledge can also be an accumulation of facts, procedural rules, or heuristics.

- *A **fact** is generally a statement representing truth about a subject matter or domain.*
- *A **procedural rule** is a rule that describes a sequence of actions.*
- *A **heuristic** is a rule of thumb based on years of experience.*

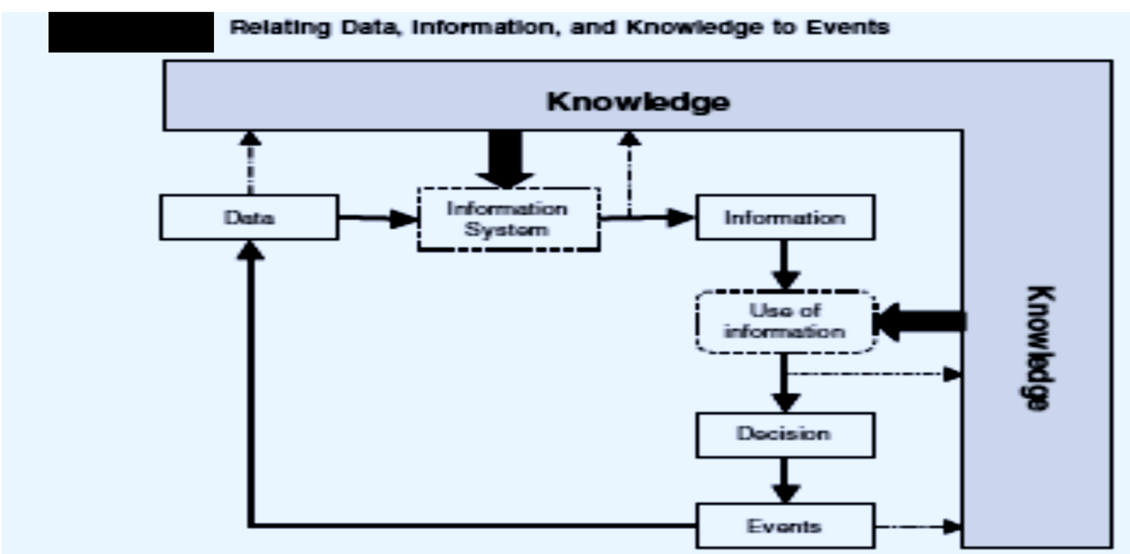
Intelligence implies the capability to acquire and apply appropriate knowledge.

Memory indicates the ability to store and retrieve relevant experience according to will.

Learning represents the skill of acquiring knowledge using the method of instruction/study.

Experience relates to the understanding that we develop through our past actions. Knowledge can develop over time through successful experience, and experience can lead to expertise.

Common sense refers to the natural and mostly unreflective opinions of humans.



1.2. Alternative Views of Knowledge:

- Knowledge can be viewed from a subjective or objective stance.

- The subjective view represents knowledge using two possible perspectives: as a state of mind or as a practice. On the other hand, the objective view represents knowledge in three possible perspectives: as an object, as access to information, or as a capability. The perspectives on knowledge are shown in Figure

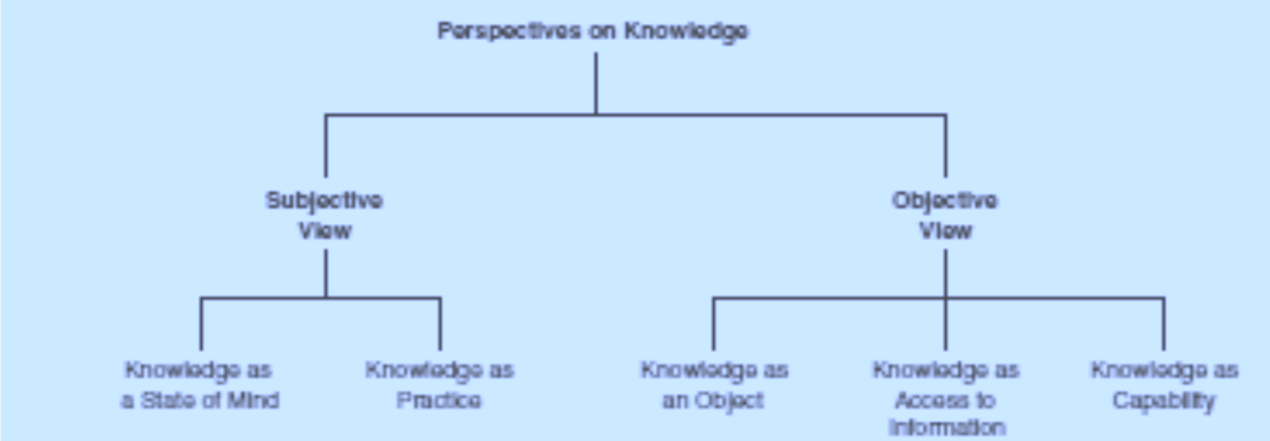


Figure 2.4 Various Perspectives on Knowledge

<u>Subjective View of Knowledge:</u>

- According to the subjective view, reality is socially constructed through interactions with individuals (Schultze 1999). Knowledge is viewed as an ongoing accomplishment that continuously affects and is influenced by social practices.
- Consequently, knowledge cannot be placed at a single location, as it has no existence independent of social practices and human experiences. According to the subjective view, knowledge could be considered from two perspectives, either as a state of mind or as practice.

<u>Knowledge as State of Mind:</u>

- This perspective considers knowledge as being a state of an individual's mind. Organizational knowledge is viewed here as the beliefs of the individuals within the organization. Moreover, to the extent the various individuals have differing experiences and backgrounds, their beliefs and hence knowledge, could differ from each other. Consequently, the focus here is on enabling individuals to enhance their personal areas of knowledge so that they can apply them to best pursue organizational goals.

<u>Knowledge as Practice:</u>

- According to this perspective, knowledge is also considered as subjective but it is viewed as being held by a group and not as being decomposable into elements possessed by individuals. Thus, from this perspective, knowledge is "neither possessed by any one agent, nor contained in any one repository" (Schultze 1999, p. 10). Moreover, knowledge resides not in anyone's head but in practice.

Objective View of Knowledge:

- The objective view is the diametrical opposite of the subjective stance. According to the objective view, reality is independent of human perceptions and can be structured in terms of a priori categories and concepts (Schultze 1999). Consequently, knowledge can be located in the form of an object or a capability that can be discovered or improved by human agents. The objective view considers knowledge from three possible perspectives.

Knowledge as Objects:

- This perspective considers knowledge as something that can be stored, transferred, and manipulated. Consistent with the definition of knowledge as a set of justified beliefs, these knowledge objects (i.e., beliefs) can exist in a variety of locations. Moreover, they can be of several different types, as discussed in the next section.

Knowledge as Access to Information:

- This perspective considers knowledge as the condition of access to information (Alavi and Leidner 2001). Thus, knowledge is viewed here as something that enables access and utilization of information. This perspective extends the above view of knowledge as objects, emphasizing the accessibility of the knowledge objects.

Knowledge as Capability:

- This perspective is consistent with the last two perspectives of knowledge as objects or as access to information. However, this perspective differs in that the focus here is on the way in which knowledge can be applied to influence action. This perspective places emphasis on knowledge as a strategic capability that can potentially be applied to seek a competitive advantage.

1.3. Different Types of Knowledge

- Knowledge has been classified and characterized in several different ways. For example, knowledge has been categorized as individual, social, causal, conditional, relational, and pragmatic and also as embodied, encoded, and procedural.

Kinds of Knowledge:

- **Deep Knowledge**: Knowledge acquired through years of proper experience.
- **Shallow Knowledge**: Minimal understanding of the problem area.
- **Knowledge as Know-How**: Accumulated lessons of practical experience.
- **Reasoning and Heuristics:** Some of the ways in which humans reason are as follows:

- **Reasoning by analogy:** This indicates relating one concept to another.
- **Formal Reasoning:** This indicates reasoning by using *deductive* (exact) or *inductive* reasoning.
- Deduction uses major and minor premises.
- In case of deductive reasoning, new knowledge is generated by using previously specified knowledge.
- Inductive reasoning implies reasoning from a set of facts to a general conclusion.
- Inductive reasoning is the basis of scientific discovery.
- A *case* is knowledge associated with an operational level.
- **Common Sense**: This implies a type of knowledge that almost every human being possess in varying forms/amounts.
- ***Procedural knowledge*** represents the understanding of how to carry out a specific procedure.
- ***Declarative knowledge*** is routine knowledge about which the expert is conscious. It is shallow knowledge that can be readily recalled since it consists of simple and uncomplicated information. This type of knowledge often resides in short-term memory.
- ***Semantic knowledge*** is highly organized, ``chunked'' knowledge that resides mainly in long-term memory. Semantic knowledge can include major concepts, vocabulary, facts, and relationships.
- ***Episodic knowledge*** represents the knowledge based on episodes (experimental information). Each episode is usually ``chunked'' in long-term memory.

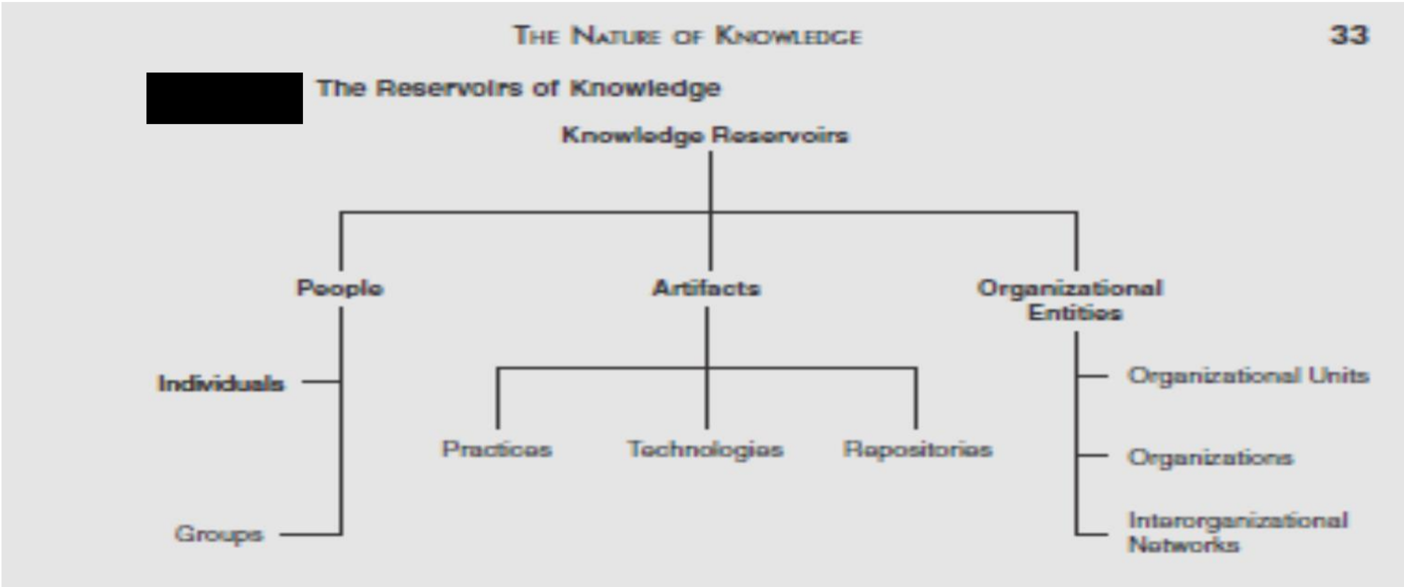
Another way of classifying knowledge is to find whether it is *tacit* or *explicit*

- ***Tacit knowledge*** usually gets embedded in human mind through experience.
- ***Explicit knowledge*** is that which is codified and digitized in documents, books, reports, spreadsheets, memos etc.

1.4. Locations of Knowledge

Knowledge resides in several different locations or reservoirs, which are summarized in Figure below They include

- **people**, including individuals and groups;
- **artifacts**, including practices, technologies, and repositories; and
- **Organizational entities**, including organizational units, organizations, and inter organizational networks.



Knowledge in People

- A considerable component of knowledge is stored in people. It could be stored either at the individual level or within a group or a collection of people. Some knowledge is stored in individuals within organizations. For instance, in professional service firms, such as consulting or law firms, considerable knowledge resides within the minds of individual members of the firm. The knowledge stored in individuals is the reason several companies continually seek ways to retain knowledge that might be lost because of individuals retiring or otherwise leaving the organization.

Knowledge in Artifacts:

- Over time, a significant amount of knowledge is stored in organizational artifacts as well. Some knowledge is stored in *practices*, organizational routines, or sequential patterns of interaction. In this case, knowledge is embedded in procedures, rules, and norms that are developed through experience over time and guide future behavior. For example, fast-food franchises often store knowledge about how to produce high-quality products in routines.

Knowledge in Organizational Entities:

- Knowledge is also stored within organizational entities. These entities can be considered at three levels: organizational units (parts of the organization), an entire organization, and in inter organizational relationships (such as the relationship between an organization and its customers).Within an organizational unit, such as a department or an office, knowledge is stored partly in the relationships among the members of the units. In other words, the organizational unit represents a formal grouping of individuals, who come together not because of common interests but rather, because of organizational structuring. Over time, as individuals occupying certain roles in an organizational unit depart and are replaced by others, the incumbents inherit some, but not all, of the knowledge developed by their predecessors.

1.5. What Is Knowledge Management?

- Knowledge management (KM) may simply be defined as doing what is needed to get the most out of knowledge resources. Although KM can be applied to individuals, it has recently attracted the attention of organizations. KM is viewed as an increasingly important discipline that promotes the creation, sharing, and leveraging of the corporation’s knowledge. Knowledge management is knowledge creation followed by interpretation, knowledge dissemination and use, and knowledge retention and refinement .Knowledge management is the process of critically managing knowledge to meet existing needs, to identify and exploit existing and acquired knowledge assets and to develop new opportunities .Knowledge management is the activity, which is concerned with strategy and tactics to manage human centered assets.

Brooking

- "The ultimate corporate resource has become information - the ultimate competitive advantage is the ability to use it - the sum of the two is knowledge management."

Source: Oxbrow & Abell (1998)

1.6. Forces Driving Knowledge Management:

- Today, organizations rely on their decision makers to make “mission critical” decisions based on inputs from multiple domains. The ideal decision maker possesses a profound understanding of specific domains that influence the decision-making process, coupled with the experience that allows her to act quickly and decisively on the information.

1. Increasing Domain Complexity:

- The complexity of the underlying knowledge domains is increasing. As a direct consequence, the complexity of the knowledge required to complete a specific business process task has increased as well. Intricacy of internal and external processes, increased competition, and the rapid advancement of technology all contribute to increasing domain complexity.

- For example, new product development no longer requires only brainstorming sessions by the freethinking product designers of the organization, but instead it requires the partnership of inter organizational teams representing various functional subunits—from finance to marketing to engineering. Thus, we see an increased emphasis from professional recruiters around the world seeking new job applicants who not only possess excellent educational and professional qualifications, but who also have outstanding communication and team-collaboration skills. These skills will enable them to share their knowledge for the benefit of the organization.

2. Accelerating Market Volatility:

- The pace of change, or volatility, within each market domain has increased rapidly in the past decade. For example, market and environmental influences can result in overnight changes in an organization. Corporate announcements of a missed financial quarterly target could send a company's capitalization, and perhaps that of a whole industry, in a downward spiral. Stock prices on Wall Street have become increasingly volatile in the past few years resulting in the phenomenon of day trading, where many nonfinancial professionals make a living from taking advantage of the steep market fluctuations.

3. Intensified Speed of Responsiveness

- The time required to take action based upon subtle changes within and across domains is decreasing.

4. Diminishing Individual Experience

- High employee turnover rates have resulted in individuals with decision-making authority having less tenure within their organizations than ever before.

1.7. Knowledge Management Systems

- Knowledge management systems utilize a variety of KM mechanisms and technologies to support the knowledge management processes.
- Knowledge management mechanisms are organizational or structural means used to promote knowledge management. The use of leading-edge information technologies (e.g., Web-based conferencing) to support KM mechanisms enables dramatic improvement in KM.
- *knowledge management systems (KMS): the synergy* between latest technologies and social/structural mechanisms

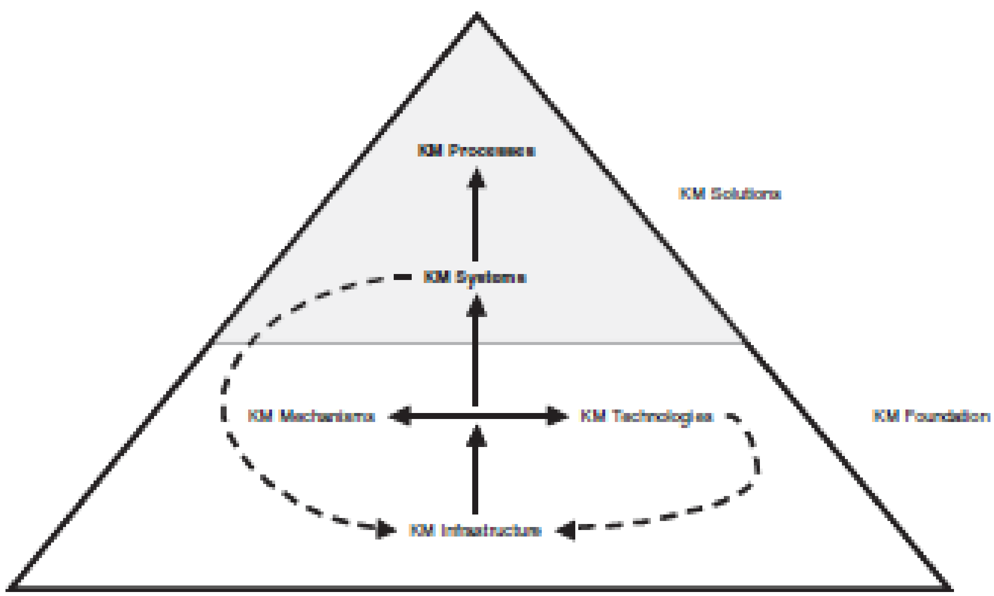
CHAPTER TWO
KNOWLEDGE MANAGEMENT FOUNDATIONS, INFRASTRUCTURE, MECHANISMS, AND TECHNOLOGIES

2.1. Knowledge Management Solutions and Foundations:

- Knowledge management depends on two broad aspects: KM solutions, which are specific in nature; and KM foundations, which are broader and more long-term. **KM solutions** refer to the ways in which specific aspects of KM can be accomplished.

- KM solutions include KM processes and KM systems**. KM foundations** are the broad organizational aspects that support KM in the short- and long-term. They include KM infrastructure, KM mechanisms, and KM technologies. Thus, KM solutions depend on KM foundations, as shown in Figure. Next, we briefly explain the three components of KM foundations and the two components of KM solutions.

[redacted] An Overview of Knowledge Management Solutions and Foundation



2.2. Knowledge Management Infrastructure:

- KM mechanisms and technologies rely on the KM infrastructure, which reflects the long-term foundation for knowledge management.
- In an organizational context, **KM infrastructure** includes five major components:
  - *organization culture,*
  - *organization structure,*
  - *information technology infrastructure,*
  - *Common knowledge, and physical environment.*

- These components are discussed in greater detail the next five sections

2.2.1. Organization Culture

- **Organization culture** reflects the norms and beliefs that guide the behavior of the organization's members.
- It is an important enabler of knowledge management in organizations.

Indeed, a survey of KM practices in U.S. companies indicated that the four most important challenges in knowledge management are nontechnical in nature and include, in order of importance.

(1) The organization's employees have no time for knowledge management;

(2) The current organization culture does not encourage knowledge sharing;

(3) Inadequate understanding of knowledge management and its benefits to the company;

(4)Inability to measure the financial benefits from knowledge management

- Knowledge management also depends to a considerable extent on the **organization structure**.
- Several aspects of organization structure are relevant. **First,** the **hierarchical structure** of the organization affects the people with whom each individual frequently interacts, and to or from whom he is consequently likely to transfer knowledge.
- **Second,** organization structures can facilitate knowledge management through **communities of practice**. A community of practice is an organic and self-organized group of individuals who are dispersed geographically or organizationally but communicate regularly to discuss issues of mutual interest.
- **Third,** organization structures can facilitate knowledge management through *specialized structures and roles* that specifically support knowledge management.

2.2.2. Information Technology Infrastructure:

- Knowledge management is also facilitated by the organization's **information technology**
- (IT) **infrastructure**. Although certain information technologies and systems are directly developed to pursue knowledge management, the organization's overall information technology infrastructure, developed to support the organization's information system's needs, also facilitates knowledge management.
- The information technology infrastructure includes data processing, storage, and communication technologies and systems. It comprises the entire spectrum of the organization's information systems, including transaction processing systems and management information systems.

2.2.3. Common Knowledge

- **Common knowledge** represents another important component of the infrastructure that enables knowledge management. It refers to the organization's cumulative experiences in comprehending a category of knowledge and activities and the organizing principles that support communication and coordination.
- Common knowledge provides unity to the organization. It includes: a common language and vocabulary, recognition of individual knowledge domains, common cognitive schema, shared norms, and elements of specialized knowledge that are common across individuals sharing knowledge.
- Common knowledge helps enhance the value of an individual expert's knowledge by integrating it with the knowledge of others. However, because the common knowledge is based on the above definition common only to an organization, this increase in value is also specific to that particular organization and does not transfer to its competitors.

A Summary of Knowledge Management Infrastructure

Dimensions of KM Infrastructure	Related Attributes
Organization Culture	Understanding of the value of KM practices
	Management support for KM at all levels
	Incentives that reward knowledge sharing
	Encouragement of interaction for the creation and sharing of knowledge
Organization Structure	Hierarchical structure of the organization (decentralization, matrix structures, emphasis on "leadership" rather than "management")
	Communities of practice
	Specialized structures and roles (Chief Knowledge Officer, KM department, traditional KM units)
Information Technology Infrastructure	Reach
	Depth
	Richness
	Aggregation
Common Knowledge	Common language and vocabulary
	Recognition of individual knowledge domains
	Common cognitive schema
	Shared norms
	Elements of specialized knowledge that are common across individuals
Physical Infrastructure	Design of buildings (offices, meeting rooms, hallways)
	Spaces specifically designed to facilitate informal knowledge sharing (coffee rooms, cafeterias, water coolers)

2.3. Knowledge Management Mechanisms:

- **Knowledge management mechanisms** are organizational or structural means used to promote knowledge management. They enable KM systems, and they are themselves supported by the KM infrastructure.
- KM mechanisms may (or may not) utilize technology, but they do involve some kind of organizational arrangement or social or structural means of facilitating KM.
- Examples of KM mechanisms include learning by doing, on-the-job training, learning by observation, and face-to-face meetings.
- More long-term KM mechanisms include the hiring of a Chief Knowledge Officer, cooperative projects across departments, traditional hierarchical relationships, organizational policies, standards, initiation process for new employees, and employee rotation across departments.

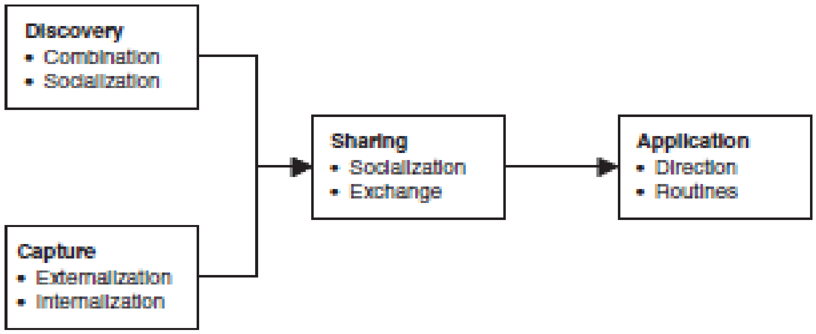
2.4. Knowledge Management Technologies:

- Thus KM technologies are intrinsically no different from information technologies, but they focus on knowledge management rather than information processing.
- KM technologies also support KM systems and benefit from the KM infrastructure, especially the information technology infrastructure.KM technologies constitute a key component of KM systems.
- Technologies that support KM include **artificial intelligence** (AI) technologies including those used for knowledge acquisition and case-based reasoning systems, electronic discussion groups, computer-based simulations, databases, decision support systems, enterprise resource planning systems, expert systems, management information systems, expertise locator systems, videoconferencing, and information repositories including best practices databases and lessons learned systems
- Examples of the use of KM technologies include World Bank's use of a combination of video interviews and hyperlinks to documents and reports to systematically record the knowledge of employees that are close to retirement. Similarly, at BP plc, desktop videoconferencing has improved communication and enabled many problems at offshore oil fields to be solved without extensive traveling.

2.5. Knowledge Management Processes:

- Thus, knowledge management relies on four main kinds of KM processes. As shown in Figure these include the processes through which knowledge is discovered or captured. It also includes the processes through which this knowledge is shared and applied. These four KM processes are supported by a set of seven KM sub processes, as shown in Figure with one sub process socialization supporting two KM processes.

[redacted] Knowledge Management Processes



<u>Knowledge Discovery:</u>

- Knowledge discovery may be defined as the development of new tacit or explicit knowledge from data and information or from the synthesis of prior knowledge.
- The discovery of new explicit knowledge relies most directly on combination, whereas the discovery of new tacit knowledge relies most directly on socialization.

Combination:

- New explicit knowledge is discovered through combination, wherein the multiple bodies of explicit knowledge are synthesized to create new, more complex sets of explicit knowledge.
- Through communication, integration, and systemization of multiple streams of explicit knowledge, new explicit knowledge is created—either incrementally or radically.
- Existing explicit knowledge, data, and information are reconfigured, recategorized and recontextualized to produce new explicit knowledge. For example, when creating a new proposal to a client, explicit data, information, and knowledge embedded in prior proposals may be combined into the new proposal.
- Also, data mining techniques may be used to uncover new relationships amongst explicit data that may be lead to create predictive or categorization models that create new knowledge.

Socialization:

- In the case of tacit knowledge, the integration of multiple streams for the creation of new knowledge occurs through the mechanism of socialization. **Socialization** is the synthesis of tacit knowledge across individuals, usually through joint activities rather than written or verbal instructions.

Knowledge Capture:

- This is the focus of **knowledge capture**, which may be defined as the process of retrieving either explicit or tacit knowledge that resides within people, artifacts, or organizational entities. Also, the knowledge being captured might reside outside the organizational boundaries including consultants, competitors, customers, suppliers, and prior employers of the organization's new employees. The knowledge capture process benefits most directly from two KM sub processes externalization and internalization.

Knowledge Sharing:

- **Knowledge sharing** is the process through which explicit or tacit knowledge is communicated to other individuals.
- Three important clarifications are in order. First, knowledge sharing means effective transfer, so that the recipient of knowledge can understand it well enough to act on it.
- Second, what is shared is knowledge rather than recommendations based on the knowledge; the former involves the recipient acquiring the shared knowledge as well as being able to take action based on it, simply involves utilization of knowledge without the recipient internalizing the shared knowledge.

Knowledge Application:

- Knowledge contributes most directly to organizational performance when it is used to make decisions and perform tasks. Of course, the process of **knowledge application** depends on the available knowledge, and knowledge itself depends on the processes of knowledge discovery, capture, and sharing.

CHAPTER-THREE

ORGANIZATIONAL IMPACTS OF KNOWLEDGE MANAGEMENT

Impact on People deals with

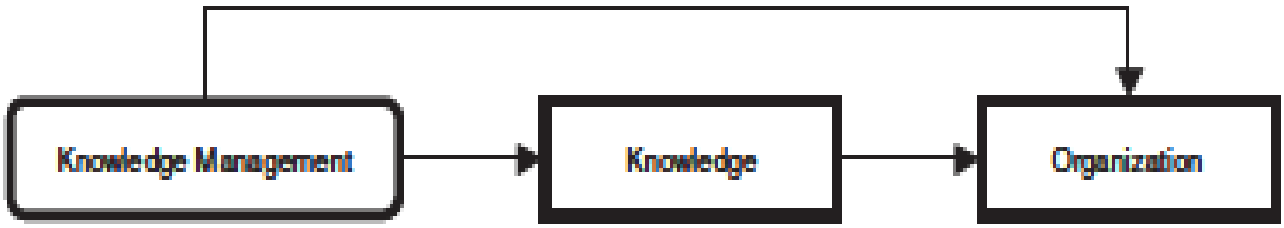
- Impact on Employee Learning, Impact on Employee Adaptability, Impact on Employee Job Satisfaction

- Impact on Processes deals with
  - Impact on Process Effectiveness, Impact on Process Efficiency, Impact on Process Innovation
- Impact on Products deals with
  - Impact on Value-added Products, Impact on Knowledge-based Products,
- Impact on Organizational Performance deals with
  - Direct Impacts on Organizational Performance, Indirect Impacts on Organizational Performance.

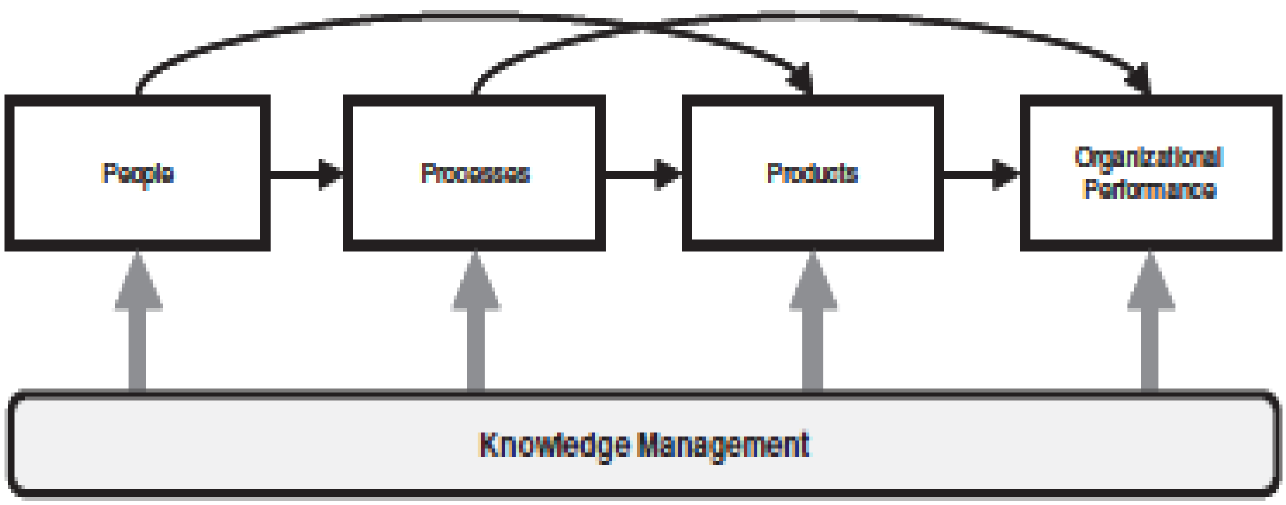
KM processes can impact organizations at these four levels in **two main ways.**

- First, KM processes can help create knowledge, which can then contribute to improved performance of organizations along the above four dimensions.
- Second, KM processes can directly cause improvements along these four dimensions.

[redacted] How Knowledge Management Impacts Organizations



[redacted] Dimensions of Organizational Impacts of Knowledge Management



- *Knowledge Management Magazine* in May 2001 (Dyer and McDonough 2001). This survey examined the status of knowledge management practices in U.S. companies, and found three top reasons why U.S. firms adopt knowledge management:

(1) Retaining expertise of employees,

(2) Enhancing customers' satisfaction with the company's products, and

(3) Increasing profits or revenues.

3.1. Impact on People

- This learning by individual employees allows the organization to be constantly growing and changing in response to the market and the technology.
- Knowledge management also causes the employees to become more flexible and enhances their job satisfaction.

3.1.1. Impact on Employee Learning

Knowledge management can help enhance the employee's learning and exposure to the latest knowledge in their fields. This can be accomplished in a variety of ways including externalization and internalization, socialization, and communities of practice.

Externalization as the process of converting tacit knowledge into explicit forms, and **internalization** as the conversion of explicit knowledge into tacit knowledge. Externalization and internalization work together in helping individuals learn.

One possible example of externalization is preparing a report on lessons learned from a project.

In preparing the report, the team members document, or externalize, the tacit knowledge they have acquired during the project. Individuals embarking on later projects can then use this report to acquire the knowledge gained by the earlier team.

Socialization also helps individuals acquire knowledge but usually through joint activities such as meetings, informal conversations, and so on. One specific, but important, way in which learning through socialization can be facilitated involves the use of a **community of practice**, as an organic and self-organized group of individuals who may be dispersed geographically or organizationally but communicate regularly to discuss issues of mutual interest.

3.1.2. Impact on Employee Adaptability

- When the knowledge management process at an organization encourages its employees to continually learn from each other, the employees are likely to possess the information and knowledge needed to adapt whenever organizational circumstances so require. Moreover, when they are aware of ongoing and potential future changes, they are less likely to be caught by surprise.
- Awareness of new ideas and involvement in free-flowing discussions not only prepare them to respond to changes, but they also make them more likely to accept change. Thus, knowledge management is likely to stimulate greater adaptability among employees.

3.1.3. Impact on Employee Job Satisfaction

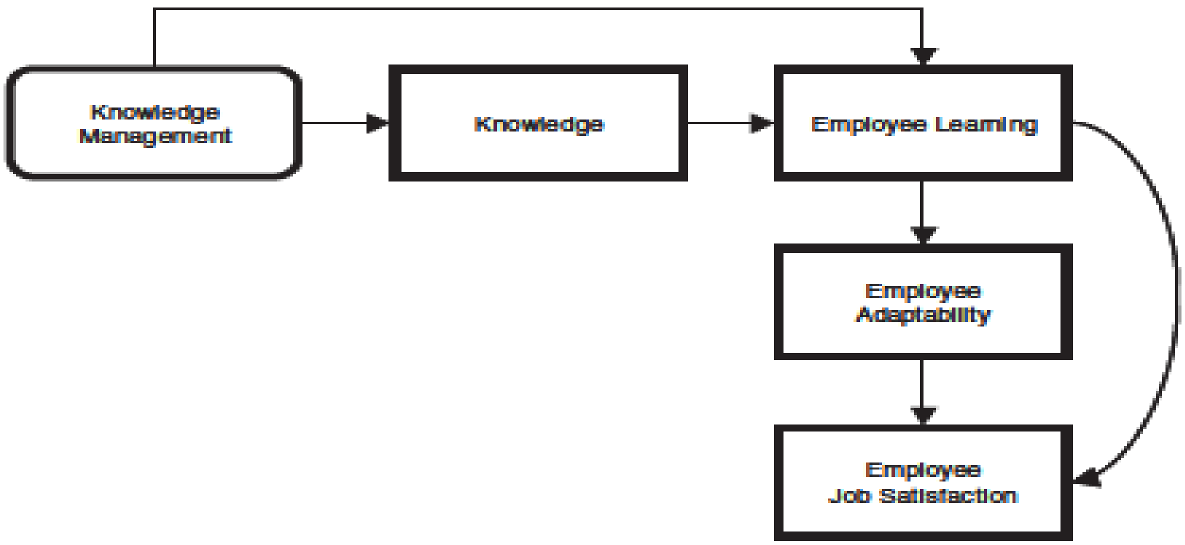
- Two benefits of knowledge management that accrue directly to individual employees have been discussed

(a) They are able to learn better than employees in firms that are lacking in KM, and

(b) They are better prepared for change. These impacts cause the employees to feel better because of the knowledge acquisition and skill enhancement and also the impacts enhance their market value relative to other organizations' employees.

- A recent study found that in organizations having more employees sharing knowledge with one another, turnover rates were reduced thereby positively affecting revenue and profit (Bontis 2003).
- In addition, knowledge management also provides employees with solutions to problems they face in case those same problems have been encountered earlier and effectively addressed. This provision of tried-and-tested solutions amplifies employee's effectiveness in performing their jobs.

[redacted] How Knowledge Management Impacts People



3.2. Impact on Processes

- Knowledge management also enables improvements in organizational processes such as marketing, manufacturing, accounting, engineering, public relations, and so forth. These impacts can be seen along three major dimensions: effectiveness, efficiency, and degree of innovation of the processes.
- These three dimensions can be characterized as follows:

  Effectiveness: Performing the most suitable processes and making the best possible decisions.

  Efficiency: Performing the processes quickly and in a low-cost fashion.

  - ***Innovation***: Performing the processes in a creative and novel fashion that improves effectiveness and efficiency—or at least marketability.

3.2.1. Impact on Process Effectiveness

- Knowledge management can enable organizations to become more effective by helping them to select and perform the most appropriate processes. Effective knowledge management enables the organization's members to collect information needed to monitor external events.
- This results in fewer surprises for the leaders of the organization and consequently reduces the need to modify plans and settle for less effective approaches.

Knowledge Management at Tearfund

- Tearfund1 is a large relief and development agency, based in the United Kingdom. It regularly responds to natural and humanitarian disasters such as floods, hurricane, typhoons, famine, and displacement.
- Tearfund was introduced to knowledge management by Paul Whiffen, who was earlier a knowledge management champion at British Petroleum (Milton 2004).
- Its knowledge management efforts were founded on the recognition that **learning from successes and failures during responses to disasters, both natural and man-made, should improve responses to later ones.** It has proved this by identifying, consolidating, and then utilizing lessons learned in response to floods in Bangladesh, the Orissa Cyclone in India, the Balkan crisis, and other disasters.
- Its knowledge management efforts comprise of two main components. First, they utilize the learning opportunities that arise during and after any major activity by involving key participants in the activity to perform after-action reviews that describe lessons learned from the activity. In each project, the key project members participate in a structured, facilitated process to identify the key lessons learned and retrieve them again when they are next required
- Second, Tearfund creates communities of practice to connect people with similar roles, issues, challenges, and knowledge needs. This enables Tear fund's employees to share their knowledge with its 350 United Kingdom and overseas partner organizations. Both these steps rely on cultural change and use of technology.

3.2.2. Impact on Process Efficiency

- Managing knowledge effectively can also enable organizations to be more productive and efficient.
- Upon exploring the "black box" of knowledge sharing within Toyota Motor Corporation's network, Dyer and Nobeoka (2000, p. 364) found that "Toyota's ability to effectively create and manage network-level knowledge sharing processes, at least partially, explains the relative productivity advantages enjoyed by Toyota and its suppliers."
- Knowledge diffusion was found to occur more quickly within Toyota's production network than in competing automaker networks. This was because Toyota's network had solved three fundamental dilemmas with regard to knowledge sharing by devising methods to:

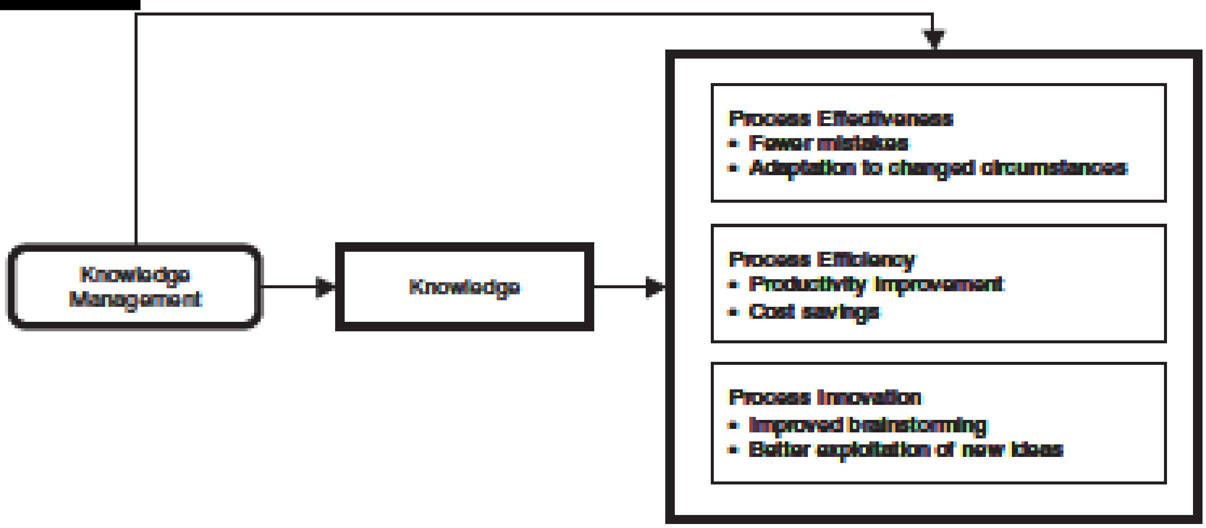
  (1**)** Motivate members to participate and openly share valuable knowledge (while preventing undesirable spillovers to competitors);2) Prevent free riders—that is, individuals who learn from others without helping others learn; and 3) Reduce the costs associated with finding and accessing different types of valuable knowledge.

- Another example of improved efficiency through knowledge management comes **from British Petroleum (Acheson 2001).** A BP exploration geologist located off the coast of Norway discovered a more efficient way of locating oil on the Atlantic seabed in 1999. This improved method involved a change in the position of the drill heads to better aim the equipment and thereby decrease the number of misses.
- The employee posted a description of the new process on BP's Intranet for everyone's benefit in the company. Within 24 hours, another engineer working on a BP well near Trinidad found the posting and e-mailed the Norwegian employee requesting necessary additional details.
- After a quick exchange of e-mail messages, the Caribbean team successfully saved five days of drilling and US$600,000.Of course in utilizing this knowledge, the employees of the Caribbean unit needed to either trust their Norwegian colleagues or be able to somehow assess the reliability of that knowledge.
- Issues of trust, knowledge ownership, and knowledge hoarding are important and need to be examined in future research.

3.2.3. Impact on Process Innovation

- Organizations can increasingly rely on knowledge shared across individuals to produce innovative solutions to problems as well as to develop more innovative organizational processes.
- Knowledge management has been found to enable riskier brainstorming (Storck and Hill 2000) and thereby enhance process innovation.
- Buckman Laboratories, discussed earlier in this chapter, linked their research and development personnel and technical specialists to their field-based marketing, sales, and technical support staffs to insure that new products were developed with the customers' needs in mind and that customer needs were quickly and accurately communicated to the product development group (Zack 1999). As a result, new knowledge and insights were effectively exploited in the marketplace leading to better products.

[redacted] How Knowledge Management Impacts Organizational Processes



3.3. Impact on Products

Knowledge management also impacts the organization's products. These impacts can be seen in two respects: **value-added products** and **knowledge-based products**. Whereas the impacts on the above dimensions come either through knowledge or directly from KM, the impacts below arise primarily from knowledge created through KM. This is depicted in Figure below.

[redacted] How Knowledge Management Impacts Products

3.3.1. Impact on Value-added Products

- Knowledge management processes can help organizations offer new products or improved products that provide a significant additional value as compared to earlier products.
- One such example is Ford's Best Practices Replication Process in manufacturing. Every year Ford headquarters provides a "task" to managers, requiring them to come up with a five percent, six percent, or seven percent improvement in key measures—for example, improvements in throughput or energy use. Upon receiving their task, the managers turn to the **best-practices** database to seek knowledge about prior successful efforts
- Value-added products also benefit from knowledge management due to the effect the latter has on organizational process innovation.

- For example, innovative processes resulting from knowledge management at Buck man Laboratories enables sales and support staff to **feed customer problems into their computer network** in order to access relevant expertise throughout the company and be able to develop innovative solutions for the customers.
- Similarly, Steelcase Inc., uses information obtained **through video ethnography** from its customers, the end users of office furniture, to understand how its products are used and then to redesign the products to make them more attractive to customers (Skyrme 2000).

3.3.2. Impact on Knowledge-based Products

- Knowledge management can also have a major impact on products that are inherently knowledge based—for example, in consulting and software development industries.
- For instance, consultants at ICL2 can quickly access and combine the best available knowledge and bid on proposals that would otherwise be too costly or too time-consuming to put together. Indeed, in such industries, knowledge management is necessary for mere survival.
- Knowledge-based products can also sometimes play an important role in traditional manufacturing firms. A classic example is Matsushita's (now Panasonic Corporation) development of an automatic bread making machine.
- In order to design the machine, Matsushita sought a master baker, observed the master baker's techniques, and then incorporated them into the machine's functionality (Nonaka and Takeuchi 1995).Similarly, companies such as Sun Microsystems have enhanced the level of customer service by placing solutions to customer problems in a shareable knowledge base. Moreover, customers can download software patches from the Internet based on their answers to an automated system that prompts customers with a series of questions aimed at diagnosing the customer needs.

3.4. Impact on Organizational Performance

- In addition to potentially impacting people, products, and processes, knowledge management may also affect the overall performance of the organization. The Deutsche Bank put it all in a nutshell when it took out a big advertisement in the *Wall Street Journal* (Stewart 2001, p. 192) that said: "Ideas are capital, the rest is just money. "This advertisement reflects the belief that investments in knowledge management should be viewed as capital investments. This investment may be capable of producing long-term benefits to the entire organization rather than as assets that provide value only at the present time. Knowledge management can impact overall organizational performance either directly or indirectly as discussed below.

3.4.1. Direct Impacts on Organizational Performance

- Direct impact of knowledge management on organizational performance occurs when knowledge is used to create innovative products that generate revenue and profit or when the knowledge management strategy is aligned with business strategy. Such a direct impact concerns revenues and/or costs and can be explicitly linked to the organization's vision or strategy.
- Consequently, measuring direct impact is relatively straightforward. It can be observed in terms of improvements in return on investment (ROI).
- For example, one account director at British Telecom (BTGroups plc) indicated that his sales team generated about US$1.5 million in new business based on briefings from a new knowledge management system (Compton2001). Similarly, speaking to the Knowledge Management World Summit in San Francisco, California, on January 11, 1999, Kenneth T. Derr, the Chairman and CEO of Chevron Corporation stated:

3.4.2. Indirect Impacts on Organizational Performance

- Indirect impact of knowledge management on organizational performance comes about through activities that are not directly linked to the organization's vision, strategy, revenues, or costs. Such effects occur, for example, through the use of knowledge management to demonstrate intellectual leadership within the industry, which, in turn, might enhance customer loyalty.
- Alternatively, it could occur through the use of knowledge to gain an advantageous negotiating position with respect to competitors or partner organizations. Unlike direct impact, however, indirect impact cannot be associated with transactions and, therefore, cannot be easily measured.
- One example of indirect benefits is the use of knowledge management to achieve economies of scale and scope. Before examining these effects, we briefly examine what we mean by economies of scale and scope. A company's output is said to exhibit **economy of scale** if the average cost of production per unit decreases with increase in output.
- Some of the reasons that result in economies of scale include: large setup cost makes low-scale production uneconomic. possibilities for specialization increase as production increases, and greater discounts from suppliers are likely when production is large scale.
- A company's output is said to exhibit **economy of scope** when the total cost of that same company producing two or more different products is less than the sum of the costs that would be incurred if each product was produced separately by a different company.

- Due to economy of scope, a firm producing multiple products has lower costs than those of its competitors focusing on fewer products. Some of the reasons that result in economies of scope include: incorporating new innovations into multiple products, joint use of production facilities, and joint marketing or administration.
- Shared knowledge of customer preferences, needs, and buying behaviors can enable cross-selling of existing products or development of new products finally, economies of scope also result from the deployment of general marketing skills and sales forces across businesses.
- Another indirect impact of knowledge management is to provide a sustainable **competitive advantage**. Knowledge can enable the organization to develop and exploit other tangible and intangible resources better than the competitors can, even though the resources themselves might not be unique.

Figure 5.6 **How Knowledge Management Impacts Organizational Performance**

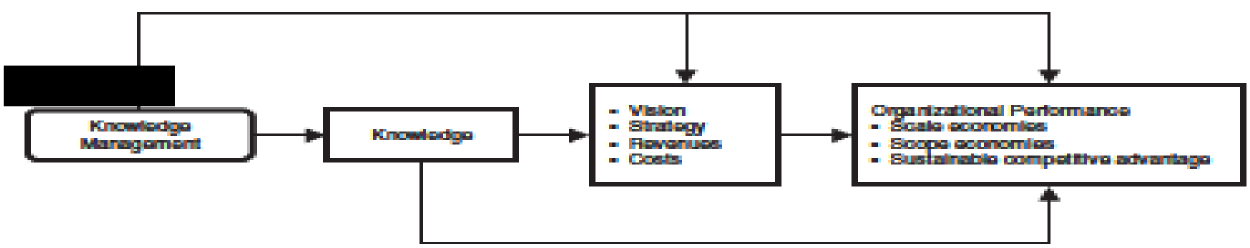


Table 5.1

A Summary of Organizational Impacts of Knowledge Management

Levels of Impact	Impacted Aspects
[redacted]	• Employee learning • Employee adaptability • Employee job satisfaction
Processes	• Process effectiveness • Process efficiency • Process innovativeness
Products	• Value-added products • Knowledge-based products
Organizational Performance	Direct impacts • Return on investment • Indirect impacts • Economies of scale and scope • Sustainable competitive advantage

- To obtain similar knowledge, the company’s competitors have to engage in similar experiences, but obtaining knowledge through experience takes time. Therefore, competitors are limited in the extent to which they can accelerate their learning through greater investment.
- Knowledge, especially context-specific tacit knowledge, tends to be unique and therefore difficult to imitate. Moreover, unlike most traditional resources, it cannot easily be purchased in a ready-to-use form.

CHAPTER-FOUR

KNOWLEDGE APPLICATION SYSTEMS: SYSTEMS THAT UTILIZE KNOWLEDGE

- Knowledge application systems are typically enabled by intelligent technologies.
- In this chapter, we introduce the reader to artificial intelligence (AI),
    - Its relationship with knowledge, and why it is an important aspect of knowledge management.
- We also summarize the most relevant intelligent technologies that underlie most KM systems,

    From rule-based expert systems, to case-based reasoning (CBR), to traditional management information systems.
- Moreover, we discuss different types of knowledge application systems:
    - Expert systems, help desk systems, and fault diagnosis systems.

Technologies for Applying Knowledge

4.1. Artificial Intelligence

- Artificial Intelligence (AI) refers to enabling computers to perform tasks that resemble human thinking ability. Much like KM and human intelligence, AI is associated with knowledge.
- Definitions for AI range from: systems that act like humans, systems that think like humans, systems that think rationally, to systems that act rationally (Russell and Norvig 2002).
- Systems that act like humans refer to those that pass the Turing Test, which refers to a computer passing a test by a human interrogator, who cannot tell whether the responses came from a person or not.
- Systems that think like humans refer to a computer program whose input to output behavior matches those of humans, for example when solving problems, like playing chess or performing a medical diagnosis.
- Systems that think rationally refer to those that follow a specific logic to solve a problem.
- People are born with a certain degree of intelligence, which they use to learn and thus acquire new knowledge. Some AI systems (also known as knowledge-based systems or knowledge application systems) try to imitate the problem-solving capabilities of skillful problem-solvers in a particular domain.
- Intelligent systems offer us technologies to manage knowledge—that is, to apply, capture, share, and discover it.
- One of the areas in AI that has witnessed the greatest popularity is knowledge-based systems, which we refer to here as knowledge application systems.

- **Knowledge application systems** are the topic of this chapter, and they basically apply knowledge to solve specific problems. Other areas of research within AI include natural language understanding, **classification**, diagnostics, design, **machine learning**, planning and scheduling, robotics, and computer vision.

- Next we describe the two most relevant intelligent technologies that underpin the development of knowledge application systems: **rule-based expert systems and case-based reasoning.**

4.1.1. Rule-based Systems

- Traditionally, the development of knowledge-based systems had been based on the use of rules or models to represent the **domain knowledge**.

- The development of such systems requires the collaboration of a subject matter expert with a knowledge engineer, the latter being responsible for the elicitation and representation of the expert's knowledge.

- The process of developing knowledge application systems requires eliciting the knowledge from the expert and representing it a form that is usable by computers. This process is called **knowledge engineering**.

- Knowledge engineers typically build knowledge application systems by first interviewing in detail the **domain expert** and representing the knowledge more commonly in a set of heuristics, or rules-of-thumb. Experts develop these rules-of-thumb over years of practical experience at solving problems.

- In order for the computer to understand these rules-of-thumb, we represent them as *production rules* or *IF-THEN* statements.

- For example: *IF* the number of employees is less than 500, *THEN* the firm is a small business is one of the rules that the SOS Advisor checks to ensure the firm is eligible for the SBIR/STTR program. Rules are the most commonly used knowledge representation paradigm, perhaps due to their intuitive implementation.

- The IF portion is the *condition* (also *premise* or *antecedent*), which tests the truth-value of a set of assertions. If the statement is true, the THEN part of the rule (also *action*, *conclusion,* or *consequence*) is also inferred as a face.

4.1.2. Case-based Reasoning Systems

- Although the rules approach to knowledge representation has produced many examples of successful knowledge application systems, many of these systems are increasingly based on the implementation of case-based reasoning (CBR) methodology.
- **Case-based reasoning** is an artificial intelligence technique designed to mimic human problem solving. Its goal is to mimic the way humans solve problems. When faced with a new problem, humans search their memories for past problems resembling the current problem and adapt the prior solution to "fit" the current problem.
- CBR is a method of analogical reasoning that utilizes old cases or experiences in an effort to solve problems, critique solutions, explain anomalous situations, or interpret situations.
- A typical case-based knowledge application system will consist of the following processes:

1. ***Search the case library for similar cases.*** This implies utilizing a search engine that examines only the appropriate cases and not the entire case library, as it may be quite large.
2. ***Select and retrieve the most similar case(s).*** New problems are solved by first retrieving previously

Experienced cases. This implies having a means to compare each examined case to the current problem,

Quantifying their similarity, and somehow ranking them in decreasing order of similarity.

3. ***Adapt the solution for the most similar case.*** If the current problem and the most similar case are not similar enough, then the solution may have to be adapted to fit the needs of the current problem. The new problem will be solved with the aid of an old solution that has been adapted to the new problem.

4. ***Apply the generated solution and obtain feedback***. Once a solution or classification is generated by the System, it must be applied to the problem.

- Its effect on the problem is fed back to the CBR system for classification of its solution (as success or failure).

5. ***Add the newly solved problem to the case library.*** The new experience is likely to be useful in future Problem solving. This step requires identifying if the new case is worth adding to the library and placing it In the appropriate location in the case library.

- There are several variants of CBR, such as exemplar-based reasoning, instance-based reasoning, and analogy-based reasoning. These different variations of CBR are described below

1. Exemplar-based reasoning—these systems seek to solve problems through classification that is, finding the right class for the unclassified exemplar. Essentially the class of the most similar past case then becomes the solution to the classification problem, and the set of classes are the possible solutions to the problem

2. **Instance-based reasoning**—these systems require a large number of instances (or cases) that are typically simple;

3. **Analogy-based reasoning**—these systems are typically used to solve new problems based on past cases from a different domain. Analogy-based reasoning focuses on case reuse, also called the **mapping problem**, which is finding a way to map the solution of the analogue case to the present problem.

C. Constraint-based reasoning is an artificial intelligence technique that uses essentially "what cannot be done" to guide the process of finding a solution. This technique is useful in naturally constrained tasks such as planning and scheduling.

- For example, to schedule a meeting all the individuals that need to attend must be available at the same time, otherwise the "availability constraint" will be violated.

D. Model-based reasoning is an intelligent reasoning technique that uses a model of an engineered system to simulate its normal behavior. The simulated operation is compared with the behavior of a real system and noted discrepancies can lead to a diagnosis

- for example, a hurricane model can be designed and implemented to predict a hurricane's trajectory, given the set of current weather conditions such as wind speed, presence of a cold front, temperature, and so forth

E. Diagrammatic reasoning is an artificial intelligence technique that aims to understand concepts and ideas using diagrams that represent knowledge. These technologies are radically different from rule based systems or CBR systems and have very specific application areas

[redacted]

Technologies for Knowledge Application Systems

Technology	Domain Characteristics
Rule-based systems	Applicable when the domain knowledge can be defined by a manageable set of rules or heuristics.
Case-based reasoning	Applicable in weak-theory domains, that is, where an expert either doesn't exist or does not fully understand the domain. Also applicable if the experience base spans an entire organization, rather than a single individual.
Constraint-based reasoning	Applicable in domains that are defined by constraints, or what cannot be done.
Model-based reasoning (MBR)	Applicable when designing a system based on the description of the internal workings of an engineered system. This knowledge is typically available from design specifications, drawings, and books, and can be used to recognize and diagnose its abnormal operation.
Diagrammatic reasoning	Applicable when the domain is best represented by diagrams and imagery, such as when solving geometric problems.

4.2. Developing Knowledge Application Systems

- The effective implementation of the knowledge application system requires a carefully thought-out methodology.
- The **Case-Method Cycle** (Kitano 1993; Kitano and Shimazu 1996) is a methodology that describes an iterative approach to effectively develop CBR and knowledge application systems in general.
- The Case-Method Cycle describes the following **six processes**:

System development process—this process is based on standard software engineering approaches, and its goal is to develop a knowledge application system that will store new cases and retrieve relevant cases.

2. **Case library development process**—the goal of this process is to develop and maintain a large-scale **case library** that will adequately support the domain in question.

3. **System operation process**—this process is based on standard software engineering and relational database management procedures. Its goal is to define the installation, deployment, and user support of the knowledge application system.

4. **Database mining process**—this process uses rule-in ferencing techniques and statistical analysis to analyze the case library. This step could help infer new relationships between the data, which could be articulated to enhance the knowledge application system.

5. **Management process**—this process describes how the project task force will be formed and what organizational support will be provided to the project.

6. **Knowledge transfer process**—this process describes the incentive systems that will be implemented to encourage user acceptance and support of the knowledge application system.

- This step will ensure that users will feel compelled to augment the case library with new cases.

4.3. Types of Knowledge Application Systems

- Knowledge application systems include **advisor systems, fault diagnosis or troubleshooting systems, expert systems, help desk systems and decision-support systems.**
- One area where knowledge application systems are specifically important is in the implementation of **help desk technologies.**
- For example Compaq Computer Corporation implemented a help desk support technology named SMART (Acorn and Walden 1992), to assist help desk employees track calls and resolve customer service problems. Compaq's SMART system was developed to support its Customer Service Department when handling user calls through its toll-free number.
- **Fault diagnosis** is increasingly becoming a major emphasis for the development of knowledge applications systems, as we will discuss below. Fault diagnosis has been one of the main focuses of intelligent systems implementation (Davis 1984; de Kleer 1976; Genesereth 1984; Patton et al. 2000).
- One of the earliest successful implementations of knowledge application systems for the diagnosis and recovery of faults in large multi-station machine tools was CABER at Lockheed Martin Corporation (Mark et al. 1996).
- Although these milling machines are equipped with self-diagnostic capabilities, typically they resolved only 20 percent to 40 percent of the systems faults. The expectation for the CABER system is that it must help identify how the equipment experienced the fault and how to safely exit the faulted state.
- Typically, an equipment fault results in a call to the field-service engineer. For the creation of the case library that supports this system, Lockheed counted on over 10,000 records collected by the field service engineers.
- CABER augmented the self-diagnostic capabilities of the milling machine, which provided junior field-service engineers with the necessary tools to resolve the fault and reduce machine downtime.

- The first system, GenAID, is one of the earliest diagnostic knowledge application systems. GenAID is based on the use of rules and is still operational today.

Case Study: I (GenAID- Generator Artificial Intelligence Diagnostics)

- GenAID—A Knowledge Application System for Early Fault Detection at Westinghouse By the year 1990, there were over 3,000 AI-based systems in use around the world for a variety of purposes including Ace (telephone cable maintenance advisory system), XCON (computer configuration system), Dispatcher (printed-wire, board assembly, work-dispatching system), APES (electronic design), CDS (configuration-dependent part sourcing), National Dispatcher (transportation sourcing and routing), XFL (floor layout assistance), XSEL
- (Sales assistance), Compass (network management), Cooker (food-processing control), ESP (facility analysis), Ocean (computer configuration), Opgen (process planning), Trinity Mills Scheduler (scheduling), VT (elevator configuration), CDS (flexible manufacturing system cell control), GenAID (generator diagnosis), Intellect (natural language database interfacing), Mudman (drilling mud analysis), and Telestream (telemarketing assistance); (Fox 1990).
- In the early 1980s, Westinghouse Electric Corporation, a manufacturer of large power generation equipment (now Siemens Power Generation), started the development of Process Diagnosis System (PDS) also known as GenAID (Gonzalez et al. 1986).
- The goal of GenAID was to enable the early detection of abnormal operating conditions of their turbine generators, which could cause them to eventually malfunction.
- For Westinghouse's customers, electrical power utilities that operate generation plants, a plant outage could represent costs that range from $60,000 to $250,000 *per day*, depending on the size and the type of the plant.
- A generator malfunction could cause unplanned outages to repair the broken unit that could last up to six months.
- Clearly, anticipating a generator outage when it's a minor fault and before it's completely inoperative and becomes a major incident can result in corrective actions that could reduce the magnitude of the problem and thus reduce the downtime from months to perhaps days.
- GenAID was one of the first real-time, sensor-based diagnosis systems.
- The goal behind GenAID was to continuously analyze the generator sensor data; therefore anticipating major destructive incidents.

4.4. Limitations of Knowledge Application Systems

- There are some practical limitations to the development of knowledge application systems.
- These relate to the fact that most of these systems are developed to serve a task-specific domain problem and are typically not integrated with the organization's enterprise systems.
- Other limitations also exist—for example, for knowledge application systems based on CBR technologies, the following limitations apply (Kitano and Shimazu 1996):

1. ***Security:* Cases may include sensitive information.**

- Knowledge application systems must consider the incorporation of security measures, including access control according to the user's organizational role.
- If knowledge application systems do not incorporate security measures, systems may not realize their maximum value.

2. ***Scalability:*** Knowledge application systems must represent a large enough number of cases so that the majority of the new experiences are represented in the case-based system. This means the knowledge application system must reach saturation prior to its deployment. Reaching system saturation means that most typical cases would have already been reported in the system. The number of cases necessary to reach the saturation point changes according to the domain.
3. ***Speed:*** As the size of the case library grows to a more comprehensive representation of real environments, computing and searching costs will also increase.

   Therefore, developers of knowledge application systems must consider the use of complex indexing schemes that will guarantee acceptable case-retrieval times and performance levels.

   In addition, knowledge application systems may not be able to solve all the problems that they encounter. New technologies will need to be developed in order to prevent incidents in complex engineering environments. Some rule-based systems could suffer from other limitations, namely the lack of scalability. Other technologies offer a different set of limitations.

CHAPTER FIVE

KNOWLEDGE CAPTURE SYSTEMS: SYSTEMS THAT PRESERVE AND FORMALIZE KNOWLEDGE

- Knowledge capture systems are designed to help elicit and store knowledge, both tacit and explicit.
- Knowledge can be captured using mechanisms or technologies so that the captured knowledge can then be shared and used by others. Perhaps the earliest mechanisms for knowledge capture dates to the anthropological use of stories—the earliest form of art, education, and entertainment.
- Storytelling is the mechanism by which early civilizations passed on their values and their wisdom from one generation to the next.

5.1. Using Stories to Build Effective Business Plans at 3M

- Few companies rival 3M's 100 record years of innovation. From the invention of sandpaper in 1904 to the invention of masking tape in 1925 and Post-it Notes in 1980, 3M's culture is noted by its use of stories. Stories are part of 3M's sales representatives' training, award ceremonies, and in short a "habit-of-mind."
- At 3M, the power of stories is recognized as a means to "see ourselves and our business operations in complex, multidimensional forms—that we're able to discover opportunities for strategic change.
- Stories give us ways to form ideas about winning" (Shaw et al. 1998, p. 41.) Recently, recognition about the power of stories reached 3M's boardroom.
- Traditionally at 3M, business plans were presented through bulleted lists. A good story can better represent a business plan, since it includes a definition of the relationships, a sequence of events, and a subsequent priority among the items which in turn causes the strategic plan to be remembered. Therefore, stories are currently used as the basic building blocks for business plans at 3M.

5.2. What are Knowledge Capture Systems?

- **Knowledge capture systems** support the process of eliciting either explicit or tacit knowledge that may reside in people, artifacts, or organizational entities.
- These systems can help capture knowledge existing either within or outside organizational boundaries, among employees, consultants, competitors, customers, suppliers, and even prior employers of the organization's new employees.
- Knowledge capture systems rely on mechanisms and technologies that support externalization and internalization.

- Both mechanisms and technologies can support knowledge capture systems by facilitating the knowledge management processes of externalization and internalization

5.3. Knowledge Management Mechanisms for Capturing Tacit Knowledge: Using Organizational Stories

- The importance of using metaphors and stories as a mechanism for capturing and transferring tacit knowledge is increasingly drawing the attention of organizations.
- For example 3M currently uses stories as part of its business planning to set the stage, introduce dramatic conflict, reach a resolution to the challenges the company is facing, and generate excitement and commitment from all the members of the organization.
- Stories are considered to play a significant role in organizations characterized by a strong need for collaboration.
- Organizational stories are defined as a detailed narrative of past management actions, employee interactions, or other intra- or extra organizational events that are communicated informally within organizations

The following are set of guidelines for organizational storytelling:

1. Stimulate the natural telling and writing of stories.
2. Stories must be rooted in anecdotal material reflective of the community in question.
3. Stories should not represent idealized behavior.
4. An organizational program to support storytelling should not depend on externalexperts for its sustenance.
5. Organizational stories are about achieving a purpose, not entertainment.
6. be cautious of over generalizing and forgetting the particulars. What has worked in one organization may not necessarily work in others.
7. Adhere to the highest ethical standards and rules.

The following eight steps to successful storytelling will help work magic in the organization:

1. Have a clear purpose.
2. Identify and example of successful change.
3. Tell the truth.
4. Say who, what, when.
5. Trim detail.
6. Underscore the cost of failure.
7. End on a positive note.

8. Invite your audience to dream.

- But Phoel also emphasizes that to tell the story right, it is not just what you say but how you say it, that will determine its success. In fact, according to Guber, there are four kinds of truth in each effective story:

  1**. Truth to the teller**—the storyteller must be congruent to her story.

  2. **Truth to the audience**—the story must fulfill the listeners' expectations by understand what the listeners know about, meeting their emotional needs, and telling the story in an interactive fashion.

  3. **Truth to the moment**—since great storytellers prepares obsessively and never tell a story the same way twice.

  4. **Truth to the mission**—since great storytellers are devoted to the cause, which is embodied in the story, capturing and expressing the values that she believes in and wants others to adopt as their own.

Other important considerations in the design of an effective organizational storytelling program include:

1. People must agree with the idea that this could be an effective means of capturing and transferring tacit organizational knowledge.
2. Identify people in the organization willing to share how they learned from others about how to do their jobs.
3. Metaphors are a way to confront difficult organizational issues.
4. Stories can only transfer knowledge if the listener is interested in learning from them.

5.4. Designing the Knowledge Capture System

- The first system is based on the use of **concept maps** as a knowledge modeling tool.
- The second system is based on the use of **context-based reasoning (CxBR)** to simulate human behavior.

5.4.1. Concept Maps

- Concept maps, aim to represent knowledge through *concepts* enclosed in circles or boxes of some types, which are related via connecting lines or *propositions.*
- Concepts are perceived regularities in events or objects that are designated by a label.In the simplest form, **a concept map contains just two concepts connected by a linking word to form a single *proposition*, also called a semantic unit or *unit of meaning.***
- In educational settings, concept-mapping techniques have been applied to many fields of knowledge.
- Their rich expressive power derives from each map's ability to allow its creator the use of a virtually unlimited set of linking words to show how meanings have been developed. Consequently, maps having similar concepts can vary from one context to another.

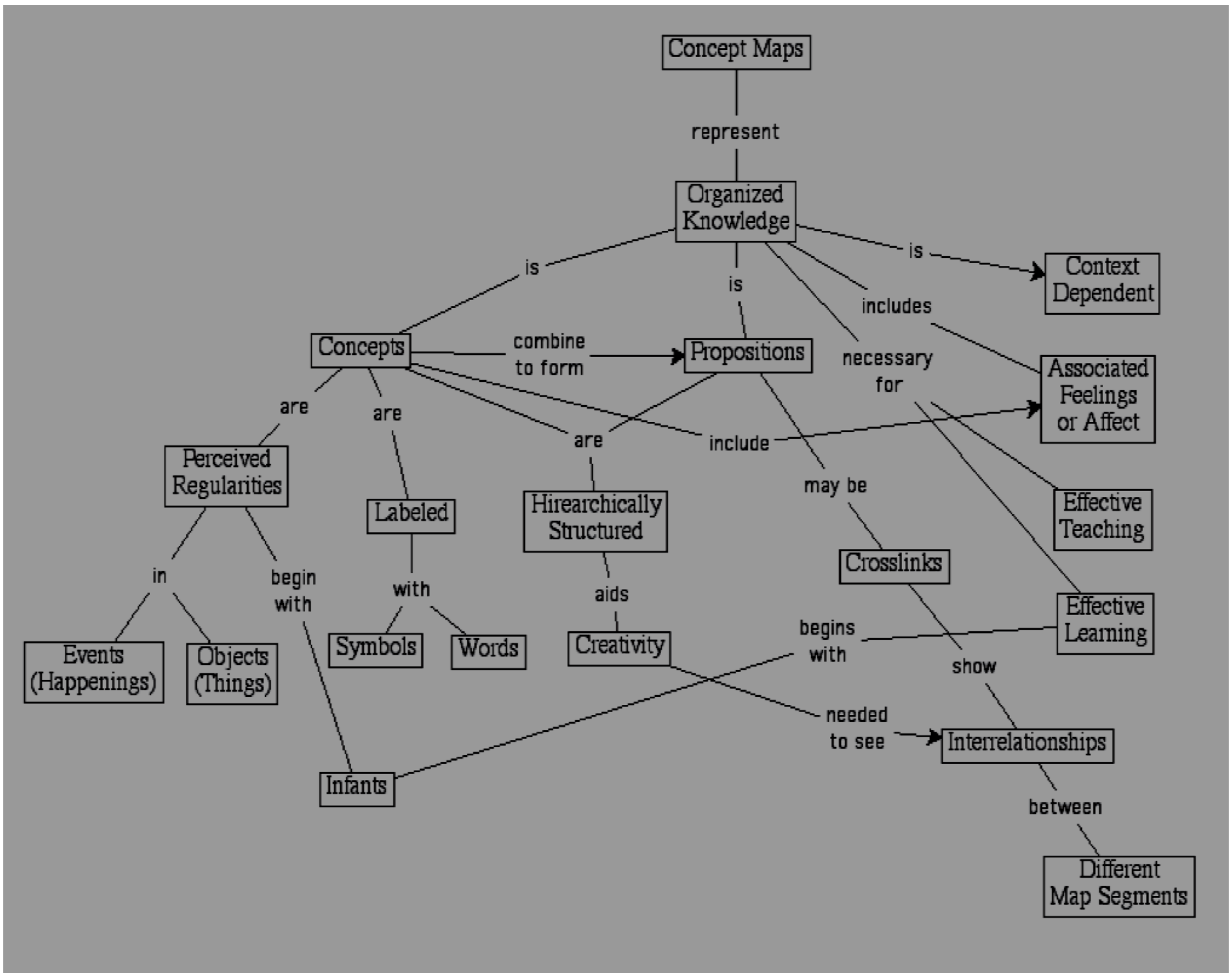
- Also, concept maps may be used to measure a particular person's knowledge about a given topic in a specific context. Concept maps can help formalize and capture an expert's domain knowledge in an easy way and to understand representation of an expert's domain knowledge.
- **Figure 7.2** shows a segment of a concept map from the domain of nuclear cardiology.

Knowledge Capture Systems Based on Concept Maps

- The goal of **Cmap Tools,** a concept map-based browser, is to capture the knowledge of experts.
- The navigation problem, an important concern in hypermedia systems, is alleviated by the use of concept maps, which serve as guides in the traversing of logical linkages among clusters of related objects. The Cmap- Tools extend the use of concept maps beyond knowledge representation to serve as the browsing interface to a domain of knowledge.

  Figure 7.3 shows the concept map-based browser as the interface for the explanation subsystem of a nuclear cardiology expert system.
- Each of the concept nodes represents an abstraction for a specific cardiology pathology, which is fully described by the icons at the concept node.
- For the cardiologist, the image results of a Nuclear Medicine Radionuclide Ventriculogram2 scan resembling a picture of "asymmetric blue fingers" (later depicted in Figure 7.4) is a sign of myocardial ischemia or chronic heart failure. Clearly the first patient will quickly need to be rushed to a hospital for emergency surgery, while the second may be given medication and a diet to relieve him of his symptoms.
- The icons below the concept nodes provide access to auxiliary information that helps explain the concepts in the form of pictures, images, audio-video clips, text, Internet links, or other concept maps related to the topic.These linked media resources and concept maps can be located anywhere accessible via the Internet.
- The browser provides a window showing the hierarchical ordering of maps, highlights the current location of the user in the hierarchy, and permits movement to any other map by clicking on the desired map in the hierarchy. This concept map-based interface provides a unique way of organizing and browsing knowledge about any domain.
- CmapTools provides a practical application of the idea of utilizing concept maps to capture and formalize knowledge resulting in context-rich knowledge representation models that can be viewed and shared through the Internet.
- CmapTools takes advantage of the richness provided by multimedia, providing an effective platform for aspiring students to learn from subject-matter experts.

- Another advantage of using concept maps for knowledge representation is that, because of their hierarchical organization, concept maps can easily scale to large quantities of information. This particular characteristic can then enable the easy integration of domain concepts together.
- CmapTools has been showed to facilitate virtual collaboration and the creation of concept maps at a distance, which are stored on public servers that can be accessed via the Internet**.**



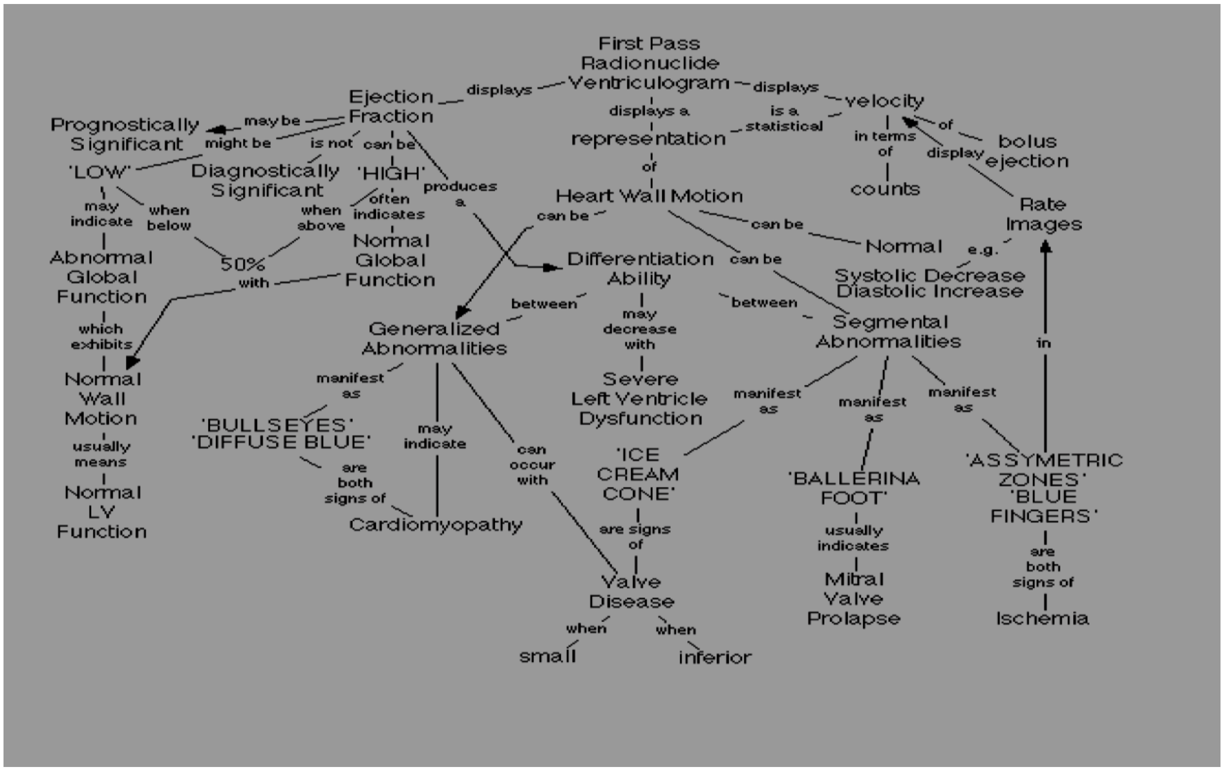
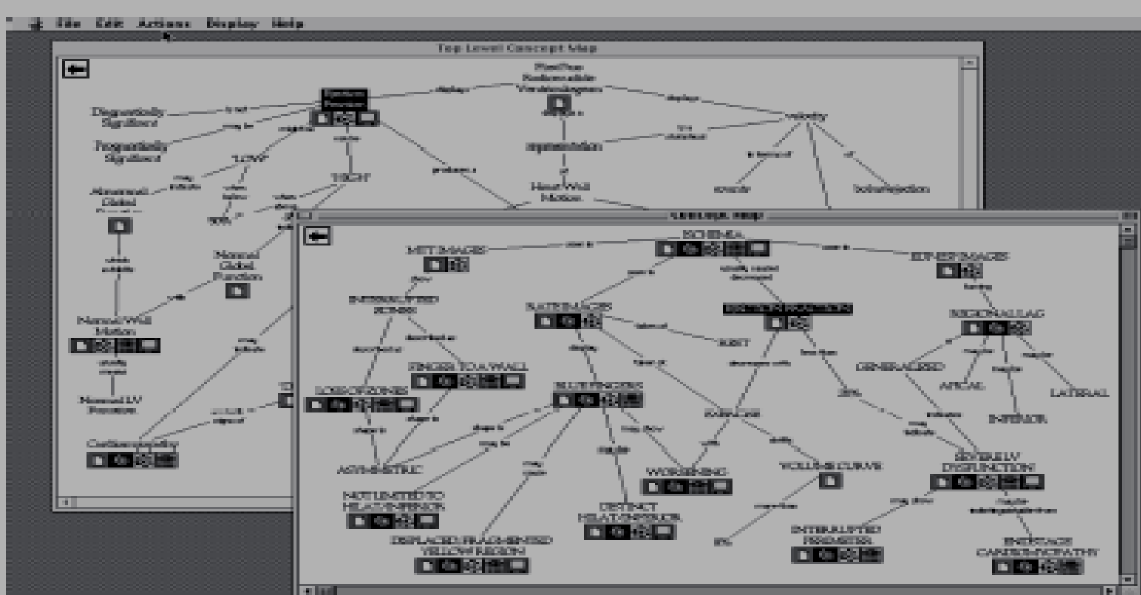
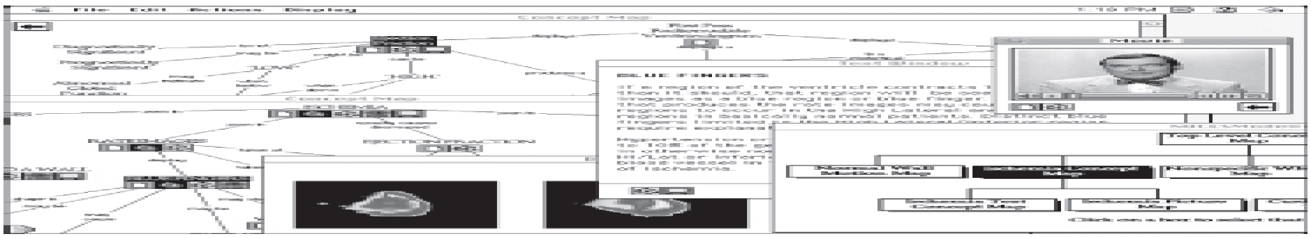


Figure 7.3 Segment of a Concept Map from the Domain of Nuclear Cardiology, Represented using CmapTools



Source: Ford et al. 1996.

Figure 7.4 The Explanation Subsystem Based on the Concept Map



Source: Ford et al. 1996.

5.4.2. Context-based Reasoning

- Knowledge Representation Through the Use of Context-based Reasoning is defined as pertaining to the short term positioning of the organization relative to its markets, competitors, and suppliers and is contrasted to strategic knowledge, which pertains to the long-term positioning of the organization in terms of its corporate vision and strategies for achieving that vision.
- In the context of this example tactical knowledge refers to the human ability that enables domain experts to assess the situation at hand (therefore short-term) among a myriad of inputs, select a plan that best addresses the current situation, and execute that plan (Gonzalez and Ahlers 1998; Thorndike and Wescort 1984).

Consider the following scenario:

- Context-based Reasoning is a human behavior representation paradigm specifically designed to effectively represent human tactical behavior.

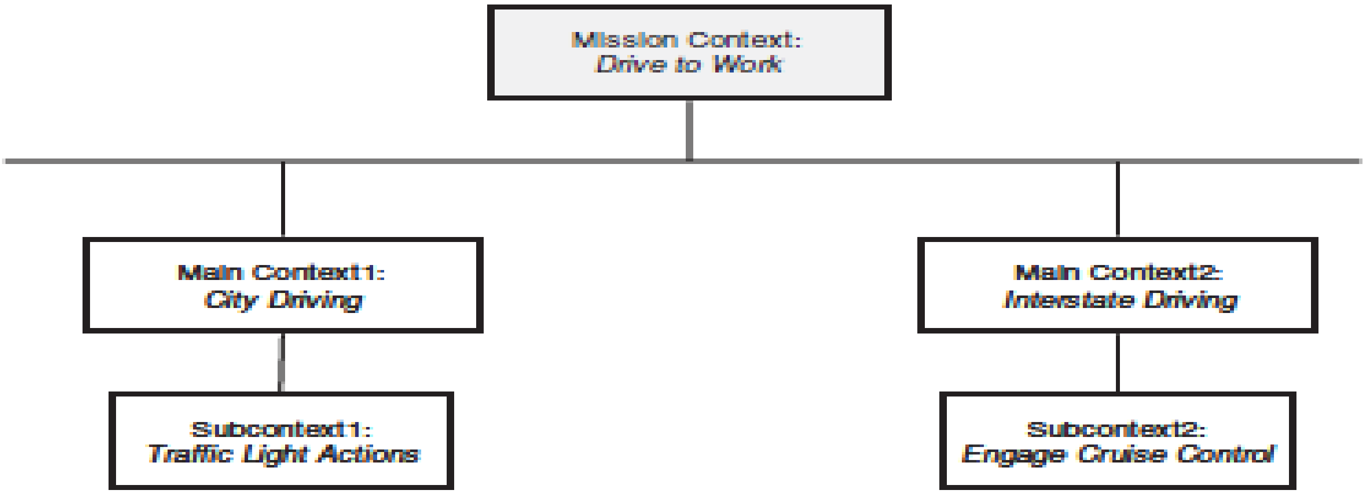
➢ Tactical behavior is defined as: “the continuous and dynamic process of decision making by a performing agent (human or otherwise) who interacts with his/its environment while attempting to carry out a mission in that environment”. A tactical situation calls for a set of actions and procedures that properly address the current situation.

➢ In the case of a driver, for example, these actions could include maintaining the car in its proper lane, stopping at a stop sign, and not exceeding the speed limit (by much). The set of actions and procedures is described as the context. As the situation evolves, a transition to another context or set of actions and procedures may be required to address the new situation

➢ For example, when a driver exits an interstate highway onto a city street, a different set of functions and procedures will be necessary to manage this new situation. In addition, one must be aware of cross traffic, traffic lights, and so forth that would not have to be considered when driving on interstate highway. What is likely to happen in a context or current situation is limited by the context itself.

- Continuing with the same example, one would not have to worry about operating the cruise control while waiting at a traffic light. However, that could be a potential action while driving on the interstate.

Figure 7.5 Context Hierarchy



Source: Gonzalez et al. 2002.

- In this sense, CxBR is hierarchical and modular and a sample hierarchy is depicted in Figure 7.5.
- The **mission context** defines the scope of the mission, its goals, the plan, and the constraints imposed (time, weather, etc). The **main context** contains functions, rules, and a list of compatible subsequent main contexts.
- Identification of a new situation can now be simplified because only a limited number of all situations are possible under the currently active context.
- **Sub Contexts** are abstractions of functions performed by the main context, which may be too complex for one function or that may be employed by other main contexts. This encourages re-usability. Sub contexts are activated by rules in the active main context. They will deactivate themselves upon completion of their actions.

CHAPTER-SIX

KNOWLEDGE SHARING SYSTEMS: SYSTEMS THAT ORGANIZE AND DISTRIBUTE KNOWLEDGE

- Knowledge sharing systems are designed to help users share their knowledge, both tacit and explicit. Most of the knowledge management systems in place at organizations are designed to share the explicit knowledge of individuals and organizations, and these are the focus of this chapter. These systems are also referred to as **knowledge repositories**.

- Systems that support tacit knowledge sharing are those typically utilized by communities of practice, finally, we discuss issues about communities of practice and how KM systems can support tacit knowledge sharing.

- **Corporate memory** (also known as an organizational memory) is made up of the aggregate intellectual assets of an organization. It is the combination of both explicit and tacit knowledge that may or may not be explicitly documented but which is specifically referenced and crucial to the operation and competitiveness of an organization.

6.1. What Are Knowledge Sharing Systems?

- **Knowledge sharing systems** can be described as systems that enable members of an organization to acquire tacit and explicit knowledge from each other.

- Knowledge sharing systems may also be viewed as knowledge markets: just as markets require adequate liquidity to guarantee a fair exchange of products, knowledge sharing systems must attract a critical volume of knowledge seekers and knowledge owners in order to be effective.

In a knowledge sharing system, knowledge owners will:

1. Want to share their knowledge with a controllable and trusted group,

2. Decide when to share and the conditions for sharing, and

3. Seek a fair exchange, or reward, for sharing their knowledge.

By the same token, knowledge seekers may:

1. Not be aware of all the possibilities for sharing, thus the knowledge repository will typically help them through searching and ranking, and

2. Want to decide on the conditions for knowledge acquisition.

6.2. Designing the Knowledge Sharing System

- The main function of a knowledge sharing system is "to enhance the organization's competitiveness by improving the way it manages its knowledge".

- The creation of a knowledge sharing system is based on the organization of digital media, including documents, Web-links, and the like, which represent the explicit organizational knowledge.

The crucial requirements for the success of a knowledge sharing system in industrial practice includes:

1. **Collection and systematic organization of information from various sources.**

- Most organizational business processes require information and data including e-mails, electronic documents such as specifications, and even paper documents.

- This requisite information may be dispersed through the organization.

- This first step requires the organization and collection of this information throughout the organization.

3. Exploiting user feedback for maintenance and evolution.

- Knowledge sharing systems should concentrate on capturing the knowledge of the organization's members.

- This includes options for maintenance and user feedback so the knowledge can be kept fresh and relevant.

4. Integration into existing environment. Knowledge sharing systems must be integrated into an organization's information flow by integrating with the IT tools currently used to perform the business tasks.

- Humans, by nature, will tend to avoid efforts to formalize knowledge. (Ever met a computer programmer that enjoys adding comments to her code?).

- In fact, as a rule-of-thumb, if the effort required in formalizing knowledge is too high, it should be left informal to be described by humans and not attempt to be made explicit.

6.3. Barriers to the Use of Knowledge Sharing Systems

- Many organizations, specifically science- and engineering-oriented firms, are characterized by a culture known as the **not-invented-here syndrome (NIH)**. In other words, solutions that are not invented at the organizational subunit are considered worthless.

- Organizations suffering from this syndrome tend to essentially reward employees for "inventing" new solutions, rather than reusing solutions developed within and outside the organization. Organizations that foster the not-invented-here syndrome discourage knowledge seekers from participating in the knowledge market, since the organizational rewards are tied to creating knowledge and not necessarily to sharing and applying existing knowledge.

Recent research has also pointed out some of the other reasons why knowledge sharing systems may fail:

1. If they don't integrate humans, processes, and technology—since technology alone will not achieve acceptance. If both people and processes, the main component in delivering organizational goals, are not adequately associated with the knowledge sharing systems.
   - In fact, KM approaches are likely to fail if they are designed as stand-alone solutions outside of the process context.
2. If they attempt to target a monolithic organizational memory—memories to be useful must be both an artifact that holds its state and an artifact embedded in organizational and individual processes.
   - Furthermore, to be useful memory objects must be decontextualized by the creator and re-contextualized by the user. Finally, to be useful memories must tag an authenticity marker.
3. If they don't measure and state their benefits—this is a requirement of any successful business initiative.
4. If they store knowledge in textual representations—knowledge artifacts that are stored in textual format may lack the adequate representation structure, including long texts that are hard to review, read, and interpret—therefore, almost guaranteeing their lack of reusability and vital contents due to their difficulty in comprehension.
5. If users are afraid of the consequences of their contributions—in addition to the importance of the organization to provide incentives for the employees' contributions to the knowledge repository, there may be some organizational barriers that actively act against knowledge sharing.
   - For example, employees may be afraid that their contributions may be taken out of context, may aid competitors, may cause an information security breach, and may lack the necessary validation to be useful to others.
6. If users perceive a lack of leadership support, lack an understanding of the generalities that would make their knowledge useful, or just don't feel it's worth their time to make a contribution.

6.4. Specific Types of Knowledge Sharing Systems

- Knowledge sharing systems are classified according to their attributes. These specific types of knowledge sharing systems include:

1. Incident report databases
2. Alert systems
3. Best practices databases
4. Lessons learned systems
5. Expertise locator systems

6.4.1. Incident Report Databases

- **Incident report databases** are used to disseminate information related to incidents or malfunctions, for example, of field equipment (like sensing equipment outages) or software (like bug reports).
- Incident reports typically describe the incident together with explanations of the incident, although they may not suggest any recommendations.
- Incident reports are typically used in the context of safety and accident investigations. As an example, the U.S. Department of Energy (DOE) disseminates chemical mishaps through their Chemical Occurrences Web page (U.S. DOE 2009).

6.4.2. Alert Systems

- **Alert systems** were originally intended to disseminate information about a negative experience that has occurred or is expected to occur. However, recent applications also include increasing exposure to positive experiences.
- Alert systems could be used to report problems experienced with a technology, such as an alert system that issues recalls for consumer products.
- Alert systems could also be used to share more positive experiences, such as Grants.gov, which offers registered users alerts to funding opportunities that match a set of user-specified keywords.

6.4.3. Best Practices Databases

- **Best practices databases** describe successful efforts, typically from the re-engineering of **business processes** that could be applicable to organizational processes.
- Best practices differ from lessons learned in that they capture only successful events, which may not be derived from experience.
- Best practices are expected to represent business practices that are applicable to multiple organizations in the same sector and are sometimes used to benchmark organizational processes.

6.4.5. Lessons Learned Systems (LLS)

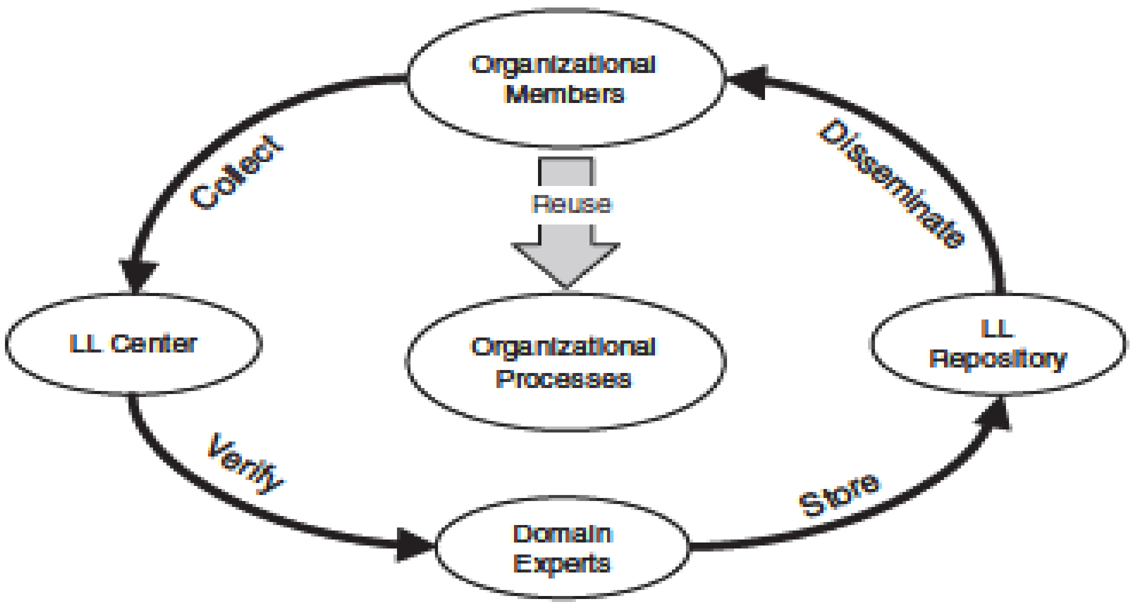
- The goal of lessons learned systems are "to capture and provide lessons that can benefit employees who encounter situations that closely resemble a previous experience in a similar situation"
- LLS could be pure repositories of lessons or be sometimes intermixed with other sources of information (e.g., reports). In many instances, enhanced document management systems are supporting distributed project collaborations and their knowledge sources while actively seeking to capture and reuse lessons from project report archives.
- **Lessons learned systems** have become commonplace in organizations and on the Web. A lesson learned is knowledge or understanding gained by experience. The experience may be positive, as in a successful

test or mission, or negative, as in a mishap or failure. Successes are also considered sources of lessons learned.

A lesson must be

- **significant** in that it has a real or assumed impact on operations;
- **valid** in that is factually and technically correct;
- And **applicable** in that it identifies a specific design, process, or decision that reduces or eliminates the potential for failures and mishaps, or reinforces a positive result.

Figure 8.1 Lesson Learned Process



Source: Weber et al. 2001.

- The purpose of LLS is to support organizational processes. Figure above describes the essential tasks of LLS as **collect, verify, store, disseminate, and reuse:**

1. Collect the Lessons

- This task involves collecting the lessons (or content) that will be incorporated into the LLS. There are six possible lesson content collection methods:

a. Passive—the most common form of collection. Contributors submit lessons through a paper or Web-based form.

b. Reactive—where contributors are interviewed by a third party for lessons. The third party will submit the lesson on behalf of the contributor.

c. After-action collection—where lessons are collected during a mission debriefing, as for example, in military organizations.

d. Proactive collection—where lessons are automatically collected by an expert system, which may suggest that a lesson exists based on analysis of a specific content.

- For example, an expert system could monitor an individual's e-mail and prompt him/her when it understands that a lesson is described.

e. Active collection—where a computer-based system may scan documents to identify lessons in the presence of specific keywords or phrases.

f. Interactive collection—where a computer-based system collaborates with the lesson's author to generate clear and relevant lessons.

2. Verify the Lessons

- Typically a team of **domain experts** performs the task required by this component, which requires the verification of lessons for correctness, redundancy, consistency, and relevance.
- The verification task is critically important, but sometimes introduces a significant bottleneck in the inclusion of lessons into the LLS, since it's a time-consuming process.

3. Store the Lesson

- This task relates to the representation of the lessons in a computer-based system.
- Typical steps in this task include the indexing of lessons, formatting, and incorporating into the repository.
- In terms of the technology required to support this task, LLS could be based on structured relational or object-oriented databases as well as case libraries (case-based reasoning) or semi structured document management systems. LLS can also incorporate relevant multimedia such as audio and video, which may help illustrate important lessons.

4. Disseminate the Lesson

- This task relates to how the information is shared to promote its reuse. Six different dissemination methods have been identified:

a. Passive dissemination—where users look for lessons using a search engine.

b. Active casting—where lessons are transmitted to users that have specified relevant profiles to that particular lesson.

c. Broadcasting—where lessons are disseminated throughout an organization.

d. Active dissemination—where users are alerted to relevant lessons in the context of their work (for example by a software help-wizard that alerts a user of related automated assistance).

e. Proactive dissemination—where a system anticipates events used to predict when the user will require the assistance provided by the lesson.

f. Reactive dissemination—when a user launches the LLS in response to a specific knowledge need, for example when he launches a Help system in the context of specific software.

5. Apply the Lesson

- This task relates to whether the user has the ability to decide how to reuse the lesson.
- There are **three categories of reuse:**

a. Brows able — where the system displays a list of lessons that match the search criteria.

b. Executable — where users might have the option to execute the lesson's recommendation (as when the word processor suggests a specific spelling for a word).

c. Outcome reuse — when the system prompts users to enter the outcome of reusing a lesson in order to assess if the lesson can be replicated.

Expertise Locator Knowledge Sharing Systems

- Several different business organizations have identified the need to develop **expertise locator systems (ELS)** to help locate intellectual capital.
- The main motives for seeking an expert are as a source of information and as someone who can perform a given organizational or social function. The intent when developing these systems is to catalog knowledge competencies, including information not typically captured by human resources systems.
- Although ELS across organizations serve a similar purpose, a number of characteristics differentiate these systems:

1**. Purpose of the system**: An ELS may serve a different purpose across organizations.

- For example the purpose could be to identify experts to help solve technical problems or staff project teams, to match employee competencies with positions within the company, or to perform gap analyses that point to intellectual capital inadequacies within the organization.
- For instance, if a specific expertise domain is a critical knowledge area for an organization and the ELS points to only three experts, it may serve to identify the need to hire or internally train additional experts in that area.

2. Access Method: Most company ELS are accessed via a company's Intranet.

- However inter organizational systems such as **SAGE (Searchable Answer Generating Environment)** is accessed via the Web. Systems accessed via the Web provide experts with an increased level of visibility, but organizations may fear that such increased visibility may be luring their experts to outside job opportunities.

3. Self-assessment: Most of the expertise locator KMS in place today rely on each employee completing a self-Assessment of competencies, which is later used when searching for specific knowledge areas. Clearly there're some advantages to this approach, mainly that it allows building a repository of Organization-wide competencies quickly.

4. Participation: Defines whether the system represents expertise across the organization like at the **National Security Agency (NSA),** a department at Microsoft, or merely volunteer experts willing to share their knowledge with others.

5. Taxonomy: Refers to the specific taxonomy used to index knowledge competencies within the organization.

- Some organizations like Microsoft developed their own knowledge taxonomy—NSA's was based on O*NET, a standard published by the U.S.
- Department of Labor, and HP based their taxonomy of an existing standard published by the U.S. Library of Congress augmented by their own knowledge competencies.

6. Levels of Competencies: Refers to expressing expertise as capability levels. Levels of competencies could be defined according to Wiig's (1993) levels of proficiency classifications

- Ignorant—Totally unaware
- Beginner—Vaguely aware, no experience
- Advanced beginner—Aware, relatively unskilled
- Competent—Narrowly skilled
- Proficient—Knowledgeable in selected areas
- Expert—Highly proficient in a particular area, generally knowledgeable
- Master—Highly expert in many areas, broadly knowledgeable
- Grand Master—World-class expert in all areas of domain
- Other differentiating characteristics for ELS may include technological differences, for example, the type of underlying database, the programming language used to develop the system, or the specifics about how the data are maintained current.

CHAPTER-SEVEN

KNOWLEDGE DISCOVERY SYSTEMS: SYSTEMS THAT CREATE KNOWLEDGE

Discovered knowledge that has helped our understanding of how things work in nature. Cumulatively, their contributions have shaped our present lives in many ways. We focus on two significant ways:

1. Synthesis of new knowledge through socialization with other knowledgeable persons; and

2. Discovery by finding interesting patterns in observations typically embodied inexplicit data.

Knowledge discovery systems support the development of new tacit or explicit knowledge from data and information or from the synthesis of prior knowledge. Knowledge discovery systems rely on mechanisms and technologies that can support the combination and the socialization processes. **Knowledge discovery mechanisms** involve socialization processes. In the case of tacit knowledge, **socialization** facilitates the synthesis of tacit knowledge across individuals and the integration of multiple streams for the creation of new knowledge, usually through joint activities rather than written or verbal instructions. For example one mechanism for socialization is research conferences, which enable researchers to develop new insights through sharing their own findings. Also, when friends brainstorm and do **“back-of-the napkin” diagrams**, leading to the discovery of new knowledge that didn’t exist individually before the group activity, knowledge is created or discovered by the team. On the other hand technologies can support knowledge discovery systems by facilitating combination processes. New explicit knowledge is discovered through **combination,** wherein the multiple bodies of explicit knowledge (and/or data and/or information) are synthesized to create new, more complex sets of explicit knowledge.

7.1. Mechanisms to Discover Knowledge: Using Socialization to Create New Tacit Knowledge

Socialization is the synthesis of tacit knowledge across individuals, usually through joint activities rather than written or verbal instructions. Socialization enables the discovery of tacit knowledge through joint activities between masters and apprentices, or between researchers at an academic conference. Many Japanese companies, for example Honda, encourage socialization through “**brainstorming camps**” to resolve problems faced in R&D projects (Nonaka and Takeuchi 1995).

7.2. Technologies to Discover Knowledge: Using Data Mining to Create New Explicit Knowledge

The technologies that enable the discovery of new knowledge uncover the relationships from explicit information. Knowledge discovery technologies can be very powerful for organizations wishing to obtain an advantage over their competition. Recall that **knowledge discovery in databases (KDD)** is the process of finding and interpreting patterns from data, involving the application of algorithms to interpret the patterns generated by these algorithms (Fayyad et al. 1996). Another name for KDD is **data mining (DM)**. Although the majority of the practitioners use KDD and DM interchangeably, for some KDD is defined to involve the whole process of knowledge discovery including the application of DM techniques.

Although data mining systems have made a significant contribution in scientific fields for years, for example in breast cancer diagnosis (Kovalerchuk et al. 2000), perhaps the recent proliferation of e-commerce applications providing reams of hard data ready for analysis presents us with an excellent opportunity to make profitable use of these techniques. The increasing availability of computing power and integrated DM software tools, which are easier than ever to use, have contributed to the increasing popularity of DM applications to businesses. Many success stories have been published in the literature describing how data mining techniques have been used to create new knowledge. Here we briefly describe some of the more mature and/or specifically relevant applications of data mining to knowledge management for business.

Over the last decade, data mining techniques have been applied across business problems. **Examples of such applications are as follows:**

1. **Marketing—Predictive DM techniques**, like **artificial neural networks (ANN)**, have been used for target marketing including market segmentation. This allows the marketing departments using this approach to segment customers according to basic demographic characteristics such as gender, age group, and so forth, as well as their purchasing patterns. They have also been used to improve direct marketing campaigns through an understanding of which customers are likely to respond to new products based on their previous consumer behavior.
2. **Retail—**DM methods have likewise been used for sales forecasting. These take into consideration multiple market variables, such as customer profiling based on their purchasing habits. Techniques like **market basket analysis** also help uncover which products are likely to be purchased together.

3. **Banking**—Trading and financial forecasting have also proven to be excellent applications for DM techniques. These are used to determine derivative securities pricing, futures price forecasting, and stock performance. Inferential DM techniques have also been successful in developing scoring systems to identify credit risk and fraud. An area of recent interest is attempting to model the relationships among corporate strategy, financial health, and corporate performance.

4. **Insurance**—DM techniques have been used for segmenting customer groups to determine premium pricing and to predict claim frequencies. **Clustering techniques** have also been applied to detecting claim fraud and to aid in customer retention.
5. **Telecommunications**—Predictive DM techniques, like artificial neural networks, have been used mostly to attempt to reduce **churn**, that is, to predict when customers will attrition to a competitor. In addition, predictive techniques like neural networks can be used to predict the conditions that may cause a

customer to return. Finally, market basket analysis has been used to identify which telecommunication products are customers likely to purchase together.

6. Operations management—neural networks have been used for planning and scheduling, project management, and quality control. Diagnosis is a fertile ground for mining knowledge. Diagnostic examples typically abound in large companies with many installed systems and a wide network of service representatives. The incidents are typically documented well, and often in a highly structured form. Mining the incident database for common aspects in the behavior of particularly troublesome devices can be useful in predicting when they are likely to fail. Having this knowledge, the devices can be preventatively maintained in the short-range and designed or manufactured in a way to avoid the problem altogether in the long-term. Witten (2000) mentions a specific example where diagnostic rules were mined from 600 documented faults in rotating machinery (e.g., motors, generators) and compared to the same rules elicited from a diagnostic expert. It was found that the learned rules provided slightly better performance than the ones elicited from the expert.

7.3. Designing the Knowledge Discovery System

Discovering knowledge can be different things for different organizations. Some organizations have large databases, while others may have small ones. The problems faced by the users of data mining systems may also be quite different. Therefore, the developers of DM software face a difficult process when attempting to build tools that are considered generalizable across the entire spectrum of applications and corporate cultures. Early efforts to apply data mining in business operations faced the need to learn, primarily via trial and error, how to develop an effective approach to DM. In fact, as early adopters of DM observed an exploding interest in the application of techniques, the need to develop a standard process model for KDD became apparent. This standard should be well-reasoned, nonproprietary, and freely available to all DM practitioners.

In 1999, a consortium of vendors and early adopters of DM applications for business operations—consisting of Daimler-Chrysler (then Daimler-Benz AG, Germany), CR Systems Engineering Copenhagen (Denmark), SPSS/Integral Solutions Ltd. (England), and OHRA Verzegeringen en Bank Groep B.V. (The Netherlands) — developed a set of specifications called **Cross-Industry Standard Process for Data Mining (CRISP-DM)** (Brachman and Anand 1996; Chapman et al. 2000; Edelstein 1999). CRISP-DM is an industry consortium that developed an industry-neutral and tool-neutral process for data mining. CRISP-DM defines a hierarchical process model that defines the basic steps of data mining for **knowledge discovery as follows:**

7.3.1. Business Understanding

The first requirement for knowledge discovery is to **understand the business** problem. In other words to obtain the highest benefit from data mining, there must be a clear statement of the business objectives. For example, a business goal could be "to increase the response rate of direct mail marketing." An economic justification based on the return of investment of more effective direct mail marketing may be necessary to justify the expense of the data mining study. This step also involves an assessment of the current situation, for example: the current response rate to direct mail is 1 percent. Results of the study showed that using 35 percent of the current sample population for direct mail (the one that is likely to buy the product), a marketing campaign could reach 80 percent of the prospective buyers. In other words, the majority of the people in a marketing campaign who receive a target mail do not purchase the product. This example illustrates how you could effectively isolate 80 percent of the prospective buyers by mailing only to 35 percent of the customers in a sample marketing campaign database. Identifying the most likely prospective buyers from the sample and targeting the direct mail to those customers could save the organization significant costs, mainly those associated with mailing a piece to 65 percent of the customers who are the least likely to buy the new product offering. The maximum profit occurs from mailing to the 35 percent of the customers that are most likely to buy the new product. Finally, this step also includes the specification of a project plan for the DM study.

7.3.2. Data Understanding

One of the most important tenets in data engineering is "know thy data." Knowing the data well can permit the designers to tailor the algorithm or tools used for data mining to their specific problem. This maximizes the chances for success as well as the efficiency and effectiveness of the knowledge discovery system. This step, together with preparation and modeling, consumes most of the resources required for the study. In fact, data understanding and preparation may take from 50 percent to 80 percent of the time and effort required for the entire knowledge discovery process. Typically, data collection for the data mining project requires the creation of a database, although a spreadsheet may be just as adequate. Data mining doesn't require data collection in a **data warehouse** and in the case the organization is equipped with a data warehouse, its best not to attempt to manipulate the data warehouse directly for the purpose of the DM study. Furthermore, the structure of the data warehouse may not lend itself for the type of data manipulation required. Finally, the construction of a data warehouse that integrates data from multiple sources into a single database is typically a huge endeavor that could extend a number of years and cost millions of dollars (Gray and Watson 1998). Most data mining tools enable the input data to take many possible formats, and the data transformation is transparent to the user.

The steps required for the data understanding process are as follows:

a. Data Collection

This step defines the data sources for the study, including the use of external public data (e.g., real estate tax folio) and proprietary databases (e.g., contact information for businesses in a particular zip code). The

data collection report typically includes the following: a description of the data source, data owner, who (organization and person) maintains the data, cost (if purchased), storage format and structure, size (e.g., in records, rows, etc.), physical storage characteristics, security requirements, restrictions on use, and privacy requirements.

b. Data Description

This step describes the contents of each file or table. Some of the important items in this report are number of fields (columns) and percent of records missing. Also for each field or column: data type, definition, description, source, and unit of measure, number of unique values, list and range of values. Also some other valuable specifics are about how the data were collected and the time frame when the data were collected. Finally, in the case of relational databases, it is important to know which attributes are the primary or foreign keys.

c. Data Quality and Verification

In general, good models require good data; therefore, the data must be correct and consistent. This step determines whether any data can be eliminated because of irrelevance or lack of quality. In addition, many data mining packages allow specifying which columns in a table will be ignored (for the same reasons) during the modeling phase. Furthermore, missing data can cause significant problems. Some data mining algorithms (e.g., C5.0) can handle the missing data problem by automatically massaging the data and using **surrogates** for the missing data points. Other algorithms may be sensitive to missing values. In that case, one approach would be to discard the data sample if some of the attributes or fields are missing which could cause a substantial loss of data. A better approach is to calculate a substitute value for the missing values. Substitute values could consist of the mode, median, or mean of the attribute variable depending on the data type.

d. Exploratory Analysis of the Data

Techniques such as visualization and online analytical processing (OLAP) enable preliminary data analysis. This step is necessary to develop a hypothesis of the problem to be studied and to identify the fields that are likely to be the best predictors. In addition, some values may need to be derived from the raw data, for example factors such as per capita income may be a more relevant factor to the model than the factor income.

7.3.3. Data Preparation

The steps for this task are:

a. Selection

This step requires the selection of the predictor variables and the **sample set**. Selecting the predictor variables is necessary because typically data mining algorithms don't work well if all the variables (fields or database columns) are considered as **potential predictors**. In essence, that's why data mining requires an understanding of the domain and the potential variables influencing the outcome in question. As a rule-of-thumb, the number of predictors (columns) must be smaller than the number of samples (rows) in the data set. In fact, the number of simple observations should be at least 10 to 25 times the number of predictors. As the number of predictor's increases, the computational requirement to build the model also increases. Selecting the sample set is necessary because when the data set is large, a sample of the data set can be selected to represent the complete data set. In selecting the sample, attention must be paid to the constraints imposed by sampling theory in order for the sample to be representative of the complete data set.

b. Construction and Transformation of Variables

Often, new variables must be constructed to build effective models. Examples include ratios and combination of various fields. Furthermore, some algorithms, like market basket analysis, may require data to be transformed to categorical format (integer) when in fact the raw data exist in continuous form. This may require transformations that group values in ranges like low, medium, and high.

c. Data Integration

The data set for the data mining study may reside on multiple databases, which would need to be consolidated into one database. Data consolidation may require redefinition of some of the data fields to allow for consistency. For example, different databases may relate to the same customer with different names; for instance, one database may refer to the National Aeronautics and Space Administration while other database fields may just use NASA. These incompatibilities must be reconciled prior to data integration.

d. Formatting

This step involves the reordering and reformatting of the data fields as required by the DM model.

7.3.4. Model Building and Validation

Building an accurate model is a trial-and-error process. The process often requires the data mining specialist to iteratively try several options until the best model emerges. Furthermore, different algorithms could be tried with the same data set and the results then compared to see which model yields the best results. For example, both neural network and **rule induction algorithms** could be applied to the same data set to develop a predictive model. The results from each algorithm could be compared for accuracy in their respective predictive quality. Following the model development, the models must be evaluated or validated. In constructing a model, a subset of the data is usually set aside for validation purposes. This means that the validation data set is not used to develop or train the model but to calculate the accuracy of predictive qualities of the model. The most popular validation technique is n-fold cross-validation, specifically ten-fold validation. The **tenfold validation** divides the population of the validation data set into ten approximately equal-sized data sets and then uses each of the ten holdout sets a single time to evaluate the models developed with the remaining nine training sets. For each of the ten models (the last model includes using the whole data set) the accuracy is determined, and the overall model accuracy is determined as the average of each of the model samples.

7.3.5. Evaluation and Interpretation

Once the model is determined, the validation data set is fed through the model. Because the outcome for this data set is known, the predicted results are compared with the actual results in the validation data set. This comparison yields the accuracy of the model. As a rule-of-thumb, a model accuracy of around 50 percent would be insignificant because that would be the same accuracy as for a random occurrence.

7.3.6. Deployment

This step involves implementing the "live" model within an organization to aid the decision-making process. A valid model must also make sense in the real world, and a pilot implementation is always warranted prior to deployment. Also, following implementation it's important to continue to monitor how well the model predicts the outcomes and the benefits that this brings to the organization. For example, a clustering model may be deployed to identify fraudulent Medicare claims. When the model identifies potential instances of fraud, and these instances are validated as indeed fraudulent, the savings to the organization from the deployment of the model should be captured. These early successes will then act as champions and will result in continued implementation of knowledge discovery models within the organization.

Figure 9.3 illustrates the iterative nature of the CRISP-DM process. CRISP-DM is only one of the institutions that have ongoing efforts towards streamlining the KDD process. Other similar efforts include:

1. **Customer Profile Exchange (CPEX)**: offers a vendor-neutral, XML-based open standard for facilitating the privacy-enabled interchange of customer information across disparate **enterprise** applications and systems.
2. **Data Mining Group (DMG)**: is an independent, vendor led group, which develops data mining standards, such as the Predictive Model Markup Language (PMML).

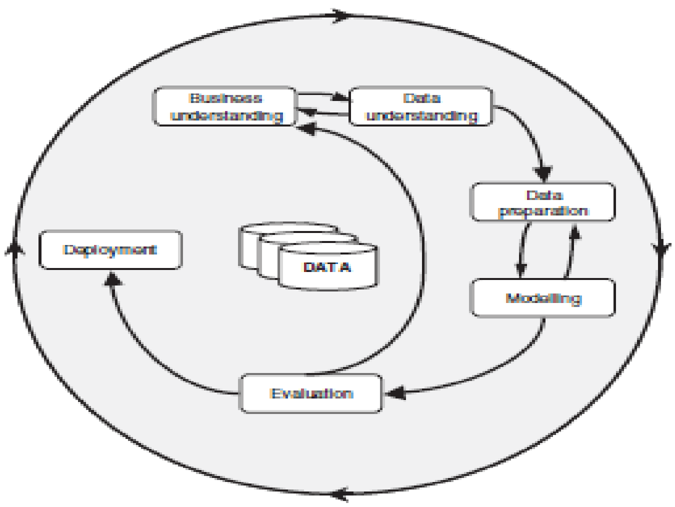
7.4. Guidelines for Employing Data Mining Techniques

Once the goal of the data mining system is understood (step 1 of the CRISP-DM process) and the data have been collected (step 2) and prepared (step 3), the next step involves building and validating the data mining model (step 4). In terms of defining the adequate data mining techniques to be used, the nature of the data will play the deciding role as to which technique is most appropriate. Input variables (also called predictors) and output variables (also called outcomes), could be continuous or discrete (also called categorical). In addition, the data could also be textual, which command a different set of data mining techniques.

In general the first step in defining the data mining technique to be used involves defining if the study is of a predictive nature, meaning there is an outcome in mind. For example, to build a model to predict credit risk for customers seeking a loan from a bank, a data set must exist that includes for each customer their corresponding characteristics (such as credit score, salary, years of education, etc.), which will serve as the predictors or inputs to the model as well as the outcome variable credit risk. In this example, there is an outcome in mind: credit risk. This is also called **inferential techniques** or supervised learning.

Data mining techniques include both statistical as well as non-statistical techniques. Statistical techniques are known as traditional data mining methods including regression, logistic regression, and multivariate methods. Non statistical techniques, also known as intelligent techniques or data-adaptive methods, include memory-based reasoning, decision trees, and neural networks.

Figure 9.3 The Iterative Nature of the KDD Process



Source: SPSS 2000.

7.5. Discovering Knowledge on the Web

Business organizations can profit greatly from mining the Web. The business need for Web DM is clear: Companies venturing in e-commerce have a dream. By analyzing the tracks people make through their Web site, they'll be able to optimize its design to maximize sales. Information about customers and their purchasing habits will let companies initiate e-mail campaigns and other activities that result in sales. Good models of customers' preferences, needs, desires, and behaviors will let companies simulate the personal relationship that businesses and their clientele had in the good old days (Edelstein 2001).

Web-based companies are expecting to discover all this knowledge in the logs maintained by their Web servers. The expectation is that a customer's path through the data may enable companies to customize their Web pages, increase the average purchase amount per customer visit to the site, and in a nutshell increased profitability.

Certainly, e-business provides a fertile ground for learning market trends as well as what the competitors are up to. Therefore, learning to mine the Web can lead to a tremendous amount of new knowledge. Web pages and documents found on the Web can provide important information at a minimal cost to develop or maintain. Text mining refers to automatically "reading" large documents (called corpora) of text written in natural language and being able to derive knowledge from the process.

Web mining is "Web crawling with on-line text mining" (Zanasi 2000). Zanasi reports about Online Analyst, a system that can mine the Web to provide competitive intelligence—a term that indicates knowledge leading to competitive advantages for a business organization. This system provides the user with an intelligent agent that surfs the Web in an intelligent fashion, and reads and quickly analyzes documents that are retrievable online. This system has the advantage that it can review many more documents than a human analyst can, even working 24 hours per day. Some of the documents may be well hidden (unintentionally or otherwise), and often times the relevant information can be found deeply buried within one document. Zanasi does not describe the techniques behind Online Analyst, probably to protect its own secrets. The system was developed by IBM-Bologna in Italy and is used as a tool for consulting.

Unfortunately, the information and data in the Web are unstructured. This can lead to difficulties when mining the Web. Conventional data mining techniques described earlier are not all applicable to Web mining, because by their nature they are limited to highly structured data. There are several differences between traditional data mining and Web mining. One significant difference is that Web mining requires linguistic analysis or natural language processing (NLP) abilities. It is estimated that 80 percent of the world's online content is based on text (Chen 2001). Web mining requires techniques from both information retrieval and artificial intelligence domains. Therefore, Web text mining techniques are rather different from the DM techniques described previously.

Web pages are indexed by the words they contain. Gerald Salton (1989) is generally considered the father of **information retrieval** (IR). IR indexing techniques consist of calculating the function **term frequency inverse document frequency (TFIDF)**. The function consists of the product of a term frequency and its inverse document frequency, which depends on the frequency of occurrence of a specific keyword-term in the text and the number of documents it appears in. The term frequency (TF) refers to how frequently a term occurs in the text, which represents the importance of the term. The inverse document frequency (IDF) increases the significance of terms that appear in fewer documents, while downplaying terms that occur in many documents. TFIDF then highlights terms that are frequently used in one document but infrequently used across the collection of documents. The net effect is that terms like cryogenics which may occur frequently in a scientist's Web page, but infrequently across the whole domain of Web pages, will result in a good indexing term.

Web Mining Techniques

Web mining techniques can be classified into four main layers (Chen 2001):

1. Linguistic Analysis/NLP

Linguistic Analysis/NLP is used to identify key concept descriptors (the who, what, when, or where), which are embedded in the textual documents. In NLP the unit of analysis is the word. These functions can be combined with other linguistic techniques such as stemming, morphological analysis, Boolean, proximity, range, and fuzzy search. For example, a **stemming algorithm** is used to remove the suffix of a word. **Stop lists** are used to eliminate words that are not good concept descriptions, such as prepositions (e.g., and, but, etc.). Linguistic techniques can be combined with statistical techniques, for example to represent grammatically correct sentences. Also **semantic analysis** is used to represent meaning in stories and sentences.

2. Statistical and Co-occurrence Analysis

Statistical and co-occurrence analysis is similar to the TFIDF function mentioned before. For example, **link analysis** is used to create conceptual associations and automatic thesauri for keyword concepts. Also **similarity functions** are used to compute co-occurrence probabilities **between concept pairs.**

3. Statistical and Neural Networks Clustering and Categorization

Like those discussed previously in "Designing the Knowledge Discovery System" section, statistical and neural networks clustering and categorization are used to group similar documents together as well as communities into domain categories. Kohonen NN techniques work well for large-scale Web text mining tasks and its results can be graphically visualized and intuitive.

4. Visualization and Human Computer Interfaces

Visualization and **human computer interfaces (HCI)** can reveal conceptual associations, which can be represented in various dimensions (one-, two-, and three dimensional views). Furthermore, interaction techniques, such as zooming, can be incorporated to infer new knowledge.

Uses for Web Data Mining

There are three types of uses for Web data mining. They are as follows:

1. Web Structure Mining

Mining the Web structure examines how the Web documents are structured and attempts to discover the model underlying the link structures of the Web. **Intra-page structure** mining evaluates the arrangement of the various HTML or XML tags within a page; **inter-page structure** refers to hyperlinks connecting one page to another. Web structure mining can be useful to categorize Web pages, and to generate relationships and similarities among Web sites (Jackson 2002).

2. Web Usage Mining

Web usage mining, also known as **clickstream analysis**, involves the identification of patterns in user navigation through Web pages in a domain. Web usage mining tries to discover knowledge about the Web surfer's behaviors through analysis of his/her interactions with the Web site including the mouse clicks, user queries, and transactions. Web usage mining includes three main tasks: preprocessing, pattern discovery, and pattern analysis (Jackson 2002):

a. **Preprocessing**—converts usage, content, and structure from different data sources into data sets ready for pattern discovery. This step is the most challenging in the data mining process, since it may involve data collection from multiple servers (including **proxy servers**), cleansing of extraneous information, and using data collected by cookies for identification purposes.
b. **Pattern analysis**—this step takes advantage of visualization and **Online Analytical Processing (OLAP**) techniques, like the ones discussed earlier, to aid understanding of the data, notice unusual values, and identify possible relationships between the **variables**.
c. **Pattern discovery**—based on the different DM techniques discussed earlier except that certain variations may be considered. For example in a market basket analysis of items purchased through a Web storefront, the click-order for the items added to the shopping cart may be significant, which is not typically studied in brick-and-mortar settings.

3. Web Content Mining

Web content mining is used to discover what a Web page is about and how to uncover new knowledge from it. Web content data include what is used to create the Web page including the text, images, audio, video, hyperlinks, and metadata. Web content mining is based on text mining and IR techniques, which consist of the organization of large amounts of textual data for most efficient retrieval—an important consideration in handling text documents. IR techniques have become increasingly important, as the amount of semi structured as well as unstructured textual data present in organizations has increased dramatically. IR techniques provide a method to efficiently access these large amounts of information.

Mining Web data is by all means a challenging task, but the rewards can be great including aiding the development of a more personalized relationship with the virtual customer, improving the virtual storefront selling process, and increasing Web-site revenues.