A Framework for Collaboration and Knowledge Management

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Abstract

Two of the most heralded recent Information Technology (IT) advances are Knowledge Management (KMS) and Collaborative Information Systems (CIS), yet neither has become a mainstream part of how many companies and knowledge workers (KWs) accomplish real work on a daily basis. We propose here two conceptual hierarchies for each of these new technologies that we believe independently may provide a structure for organizations and individuals to assess their current level of capability in each area. Further, we assert that the two hierarchies are complementary and can be integrated to provide a framework for IT capability in terms of Intellectual Bandwidth (IB.) In this paper we describe the two hierarchies and then present the integrated framework and introduce the concept of IB as the sum of an organizations' CIS and KMS capabilities. Finally we map sample technolgies into the framework and explain how the technologies enable individuals, teams and oganizations to achieve various levels of KIS and CIS capability. Future research in this area will focus on developing and validating constructs and measures of IB in terms of both KMS and CIS.

Introduction

KMS and CIS both attempt to deal with the ever increasing amount of data, information and knowledge that our hyper-connected business environment is making available. As organizations attempt to use IT to manage knowledge and enable teams to work together in more efficient and effective ways than ever before, two important trends have made KMS and CIS increasingly important. First, the proliferation of data and information that bombards individuals and organizations has made attention a critical resource. Second, computer networks have enabled individuals, groups and even organizations to communicate and work together in new ways that are changing the very structure of organizations. Results of these two trends include an increase in the number of individuals, groups, and organizations with whom we communicate and work on a regualr basis, increased variety in the number and types of IT-supported tasks in which we participate, and an increased need for IT-based tools to perform tasks, communicate, and manage knowledge for future use.

Data and Information Overload

As we have moved into the information age, the number and types of communication messages we receive has increased at an ever-increasing pace. Figure 1 shows the results of the 1999 Pitney Bowes Survey of 800 KWs.

Figure 1. Pitney Bowes Survey Results

	1999	1998	1984*
Telephone Calls	52		20
E-mails	36		4
Voicemails	23		0
S-Mails	18		10
Interoffice Memos	18		11
Faxes	14		0
Post-its	13		5
Message Slips	9		4
Pager Messages	8		0
Cell Calls	4		0
Express Mail	7		0
Total	202	190	54

*Estimated

Specific details for 1998 were not available, however the results show an increase in the number of messages from 190 in 1998 to 202 in 1999. One author estimated the number of messages by format they received in 1984, and the results show a dramatic increase in both the total number of messages and the variety of formats. The Pitney Bowes Survey also found that the percent of people with six or more interruptions per hour rose from 40% in 1998 to 45% in 1999.

In Addition today we receive messages from a variety of other sources including:

- Team Databases (NOTES/ICL TeamWare)
- Search Engine Results
- Videoconferences
- Agents
- Digital Documents
- Web Pages
- Discussion Groups (News/Usenet/etc)
- Advertising (Email/Web-based/TV/Radio)
- Tacit Knowledge
- Face-to-face Meetings
- Hallway Conversations
- Cable Television News
- Print Media (USA Today, Web Week, etc.)

There is little doubt that both the amount and type of communication events we experience has increased dramatically over the past two decades. Some authors [47, 54] have begun to question whether or not all this information is really useful or if it is just junk. Economist Herbert Simon has stated that "Attention" has become the critical resource of the information age. Somehow we must digest all this data and information and organize it into meaningful and useful knowledge, and then through wisdom make intelligent decisions and judgments about what to do. The result has been the rise of KMS and CIS as attempts to capture, structure, and contextualize the huge volume of data and information we receive.

Knowledge Management Systems

Researchers [15, 65, 78, 83] assert that organizational knowledge and its management are critical for organizational success and competitive advantage. There is a rising interest in KMS due to the increase in knowledge content of all types of work and in the proportion of workers who are KWs [74, 83]. This trend is supported by a literature survey on the development of decision support systems (DSS) applications, which reveals a growing increase in optimization and suggestion model-based DSS relative to simulation-based applications [31]. LaPlante [50] asserts that the most forward-looking KMS efforts are found at firms where leveraging IT experience directly impacts the bottom line. Figure 2 presents four categories of IT-based KMS applications. Rulke et al. [78] assert that research into how organizations identify, develop and transfer knowledge is presently in its infancy.

Figure 2. Four categories of KM IT applications

1. Sharing successful practices and access to information for IT support functions
2. Support for phone-based help desks
3. Reusing and learning from knowledge acquired during previous IT efforts
4. Bringing geographically dispersed workers together to collaborate on team tasks.

A Need for Higher Levels of Learning

Ackoff [2] asserts that the majority of computer-based systems are primarily devoted to the acquisition, processing and transmission of data and information. He also asserts that significantly less effort is devoted to the transmission of knowledge and practically no effort is spent on the transmission of understanding and even less to the transmission of wisdom. Ackoff suggests that this allocation of effort is reflected by our popular and persistent preoccupation with information in the press, on TV game shows and in such popular games as "Trivial Pursuit." Clearly more attention needs to be devoted to the conversion of data and information into what Ackoff [2] describes as "**higher levels of learning**" and toward communicating such knowledge and wisdom to others efficiently and effectively through computer-based systems.

KMS from Three Perspectives

We discuss KMS from three perspectives: historical, conceptual, and hierarchical. The historical perspective illustrates the relative recency of KMS. The conceptual perspective defines and differentiates the constructs of KMS. Finally the hierarchical perspective presents relationships among the constructs and relates them to IT organizational capability.

KMS A Historical perspective

Liebowitz [53] provides an historical perspective of KMS over the last two decades (See figure 3.) Liebowitz' list of events in KMS illustrates the relative newness of the field and its rapid development over the past twenty years.

Figure 3. Historical KMS Perspective

Yr	Entity	Event
80	DEC & Carnegie Mellon University	One of the first commercially successful Expert Systems XCON: Configures computer components
86	Dr. Karl Wiig	Coined KM concept at keynote address for United Nation's International Labor Organization
89	Large management consulting firms	Start internal efforts to formally manage knowledge
89	Price Waterhouse	One of the first to integrate KM into its business strategy
91	Nonaka and Takeuchi HBR	One of the first journal articles on KM published
93	Dr. Karl Wiig	One of the first books dedicated to KM published *(Knowledge Management Foundations)*
94	Knowledge Management Network	First KM conference held
94	Large consulting firms	First to offer KM services to clients
96+	Various firms and practitioners	Explosion of interest and activities

From [53]

KMS a Conceptual Perspective

Bellinger et al. [20] assert that although KMS is a very active area for research and development there are few references that define just what knowledge is, or how to distinguish it from other similar concepts such as data, information and wisdom. Our literature review revealed that many definitions of knowledge have been offered and they range from conceptual to practical to philosophical, and from narrow to broad in scope. The following definitions of knowledge are relevant to KMS:

> Knowledge is organized information applicable to problem solving. - Woolf [97]
>
> Knowledge is information that has been organized and analyzed to make it understandable and applicable to problem solving or decision making. - Turban and Frenzel [90]
>
> Knowledge encompasses the implicit and explicit restrictions placed upon objects (entities), operations, and relationships along with general and specific heuristics and inference procedures involved in the situation being modeled. - Sowa [82]
>
> Knowledge consists of truths and beliefs, perspectives and concepts, judgments and expectations, methodologies and know-how. - Wiig [95]
>
> Knowledge is the whole set of insights, experiences, and procedures that are considered correct and true and that therefore guide the thoughts, behaviors, and communications of people. - van der Spek and Spijkervet [92]
>
> Knowledge is reasoning about information and data to actively enable performance, problem solving, decision-making, learning, and teaching. - Beckman [19]

These definitions do offer some insight into what knowledge is at a high level of abstraction; however they do little to help us understand how IT can be used to help manage knowledge within organization.

KMS A Hierarchical Perspective

Knowledge and related concepts such as data, information, wisdom and understanding can be organized into a hierarchy that begins to offer some insights about how we might employ IT to manage knowledge. Ackoff [2] describes these concepts as **contents of learning** and suggests that they form a hierarchy of increasing value. Ackoff presents the following adage to reflect the idea of a hierarchy of increasing value:

"*An ounce of information is worth a pound of data; an ounce of knowledge is worth a pound of information; an ounce of understanding is worth a pound of knowledge; and an ounce of wisdom is worth a pound of understanding.* " [2]

KMS researchers [2, 3, 4, 5, 19, 92] distinguish between the concepts of data, information, and knowledge:
Data: Facts, Images, or sounds
(+ interpetation + meaning =)
Information: Formatted, filtered, and summarized data
(+action + application=)
Knowledge: Instincts, ideas, rules, and procedures that guide actions and decisions.

To this Tobin [87] adds Wisdom:
Data: (+relevance + purpose=)
Information: (+application=)
Knowledge: (+ intuition + experience=)
Wisdom.

To this Ackoff [3] adds understanding
Data:
Information:
Knowledge:
Understanding:
Wisdom.

Ackoff [3, 4] also distinguishes among these categories in terms their **descriptive** and **temporal** natures, by employing **when, where, who and what** to describe information, **how** to describe knowledge and **why** to describe understanding. According to Ackoff, data, information, knowledge and understanding concern what is presently known or has been known, and all relate to the past. Wisdom on the other hand, incorporates design and visions and therefore is concerned with the future. Wisdom enables creation of the future, rather than simply cognizance of the present or the past. Wisdom is not easy to obtain and one must move successively through the lower levels of the hierarchy to reach it [3, 4]. Jim Blair, Research Director at the Gartner Group, stated it this way: For KMS to be successful "*data has to become information, and information has to become wisdom* [50]."

Ackoff [3, 4] briefly defined the five categories as follows:

Data: Symbols that represent objects, events and/or their properties.

Information: Data processed to be useful; provides answers to who, what, where, and when questions. It is contained in descriptions.

Knowledge: Application of Data and Information; answers how questions. It is contained in instructions.

Understanding: Appreciation of why. It is contained in explanations.

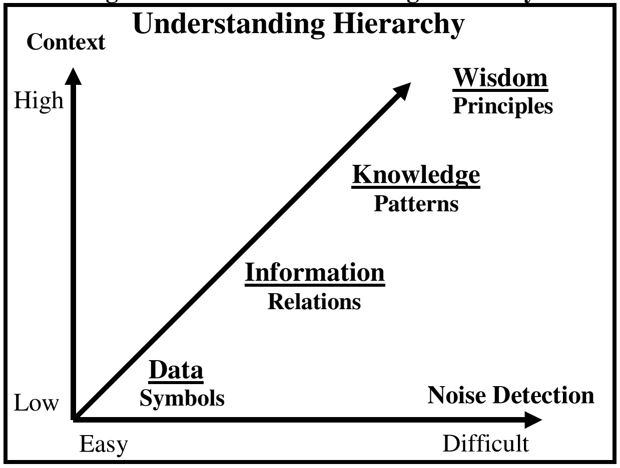
Wisdom: Evaluated Understanding. It is the ability to perceive and evaluate the long run consequences of behavior.

A Hierarchy of Understanding

We have adopted Tobin's [87] hierarchy and the four KMS levels of data, information, knowledge and wisdom. Bellinger et al. [20 contend that Ackoff's sequence may be too involved and suggest that understanding supports transitions and distinctions between the other four phases (see Figure 4.) We extend their notion, such that understanding here refers to grasping of the nature, significance, or explanation of the levels in the hierarchy in terms of three concepts: **Awareness** and **Discernment** of constructs which distinguish between the levels of understanding; **Context** in terms of how embedded the context is within a construct; and **Noise Detection** in terms of distinguishing between noise and important items.

Experience serves as a mediating construct, such that more experienced or expert individuals will more easily acquire awareness, discern relations, patterns, and principles, grasp the appropriate context, and detect and ignore noise in favor of meaningful inputs. Each of these three elements of understanding is described in detail below and represented as an axis in Figure 4.

Figure 4. KMS Understanding Hierarchy



(Adapted from [Bellinger, 2000 #1446])

Awareness and **Discernment**

The higher the level in the hierarchy the more structured the understanding required to recognize and comprehend the construct. For data to be meaningful one must understand the symbols that comprise its representation. For information to be meaningful one must understand the relations among and between the data elements that comprise its organization. For knowledge to be meaningful one must understand the patterns among and between the information that comprise its arrangement. For wisdom to be meaningful one must understand the principles that underlie the patterns within the knowledge that comprises its value and archetypes.

Experience is a mediating construct, such that more experienced or expert individuals will be able to understand symbols, relations, and patterns more easily than a novice in a given domain. Identifying and apprehending the structure of the next higher level in the hierarchy becomes more difficult and requires more experience at the higher levels. This means that data may be easier to understand in terms of its symbols than is information in terms of its relations and so on up through wisdom in terms of its principles.

Context

Bellinger et al. [21] argue that as one moves up the understanding hierarchy from data to wisdom the level of context **independence** decreases. We take a slightly different interpretation and consider how embedded the context is within the construct. We assert that as one moves up the hierarchy from data to wisdom, there is an increasing level of "implicit meaning" or context embedded within the relations, patterns, and principles associated with the various levels.

Data by itself has no context until someone interprets it and ascribes a context to it. Information has some embedded context within it by the nature of the relations that summarize and organize the data that comprise it. Knowledge has more embedded context within it through the patterns that are formed by the arrangement of the information it contains. Wisdom has the most embedded context within the principles that form its values and archetypes.

Experience is also a mediating construct for context, in that novices may find it more difficult to **ascribe context** or **interpret data** in a meaningful way or from multiple useful perspectives than experts in a given domain. Since novices may have more difficulty recognizing and comprehending relations, patterns and principles that comprise information, knowledge and wisdom respectively, they may have more difficulty inferring the appropriate context for a given issue than those with more experience or experts. As the context becomes more embedded in the constructs at higher levels, novices may find it more difficult than experts to generalize knowledge (patterns) and wisdom (principles) to other contexts.

Noise Detection

Along with all forms of learning in the understanding hierarchy comes irrelevant noise that must be detected and filtered out before meaning can be deduced from the relevant material. Detecting noise from a set of data is relatively easier than detecting noise from information, knowledge or wisdom. As the structure increases with higher levels of the hierarchy, relations, patterns and principles may confuse rather than inform or provide useful understanding or context. This is very important as time and effort can be wasted paying attention to useless noise rather than to critical information, knowledge or wisdom. Noise detection is a critical skill that can help with efficient and effective allocation of the critical resource of attention.

Here too experience is a mediating construct, as novices may be more easily distracted by irrelevant noise at any level in the hierarchy than experts. The inability of inexperienced individuals to detect noise may increase as one moves up the hierarchy due to the increasing abstractness and structure of the constructs. While increasing structure may be part of the reason higher level constructs have their context more embedded within them, it may also make detection of noise more difficult for novices.

One example of this we have seen is in our work with the United States Navy at sea. We observed that when a number of inputs of data, information and knowledge are available, such as radar blips, longitude, latitude and sea floor maps, the Admiral, who has the most experience can quickly determine that the signals are from a set of buoys and not an enemy submarine, which could not go into such shallow water. He will ignore the buoys and continue to search for other potentially threatening signals, while less experiences crew members may mistakenly be distracted by the noise of the buoys and waste valuable time, resources and effort chasing a wild goose.

Fleming [34] asserts the following:

- A collection of data is not information.
- A collection of information is not knowledge.
- A collection of knowledge is not wisdom.
- A collection of wisdom is not truth.

Fleming stresses that information, knowledge, and wisdom are more than mere collections [21]. The key point here is that the organization of a lower level into a higher level in the understanding hierarchy results in a collection with its own synergy, which represents more than the simple sum of its parts [21]. There must be some underlying organizing structure, such as relations, patterns or principles applied to a collection in order for it to move to the next level in the hierarchy.

Construct Definitions

Based on the hierarchies in the literature [3, 4, 5, 19, 20, 21, 87, 92] we elaborate on each of the four levels of the hierarchy of understanding and present computer-based examples.

Data

Data is most often **raw symbols** that **merely exist** and have **no significance** beyond that existence (in and of itself.) Ackoff [4] describes data as products of observations made by people or instruments. Bellinger [21] asserts that raw data lacks context and therefore **does not have meaning** in and of itself nor does it have any meaningful relations to anything else. To ascribe meaning to data humans create a context by associating data with other objects or providing an interpretation. To understand data one must **understand the symbols** that comprise the data.

Ackoff [4] likens data to metal ores, in that both have little or no value until they are "processed" into usable forms. Data can exist in **any form**, whether usable or not. A collection of data is not information, if there is no relation among the data elements [21, 34]. A computer analogy is that spreadsheets contain data prior to formulas being used to organize and summarize it into relationships such as an average.

Information

Information consists of data organized into meaningful **relationships** and s**tructures.** It is data that has been given **meaning through relational connection.** This meaning can be useful, but need not be. Ackoff [4] asserts that the difference between data and information is not a structural one, but is related to **functional usefulness**; information is more useful than data.

To understand information one must **understand the relations** among data elements. Information is usually **static and linear** in nature and does not provide understanding of why the data exists in the form it has [21]. Information is **factual** in nature and conveys description, definition or perspective and can provide answers to questions about **what, who, when, and where** [3, 4, 21]. A collection of information is not knowledge, if there is no pattern or repeatable process among the information elements [21, 34]. One computer analogy is how a relational database builds information from the data it stores.

Knowledge
Knowledge is information organized into meaningful **patterns** [16] and **repeatable processes** [21]. Patterns are more than mere relations of relations [16], they exemplify **completeness** and **consistency** of relations and to some extent create their own context [20]. Patterns also have **implied predictability** and **repeatability** and thus serve as archetypes [21, 80].

Patterns among data and information have the potential to represent knowledge. The pattern develops into knowledge when someone has an awareness and understanding of the pattern and its implications [21]. Knowledge represented through patterns has a tendency to be more self-contextualizing than information or data. Patterns are seldom static in nature, and if one understands a pattern it will exhibit a great deal of predictability and reliability in terms of how it will evolve over time. Patterns that represent knowledge have a higher level of completeness than information [21]. To understand knowledge one must **understand the patterns** among the informaiton that comprises it.

Knowledge is an **appropriate collection of information**, such that it's **intent is to be useful.** Knowledge is **procedural** in nature and encompasses strategy, practice, method or approach and may provide answers to questions about **how** to perform procedures in terms that may be order-specific and/or time-specific [3, 4, 21]. A collection of knowledge is not wisdom, if it is not organized based on principles that imply value [21, 34]. Some knowledge-based software applications include modeling, simulation, expert systems and agents.

Wisdom
Wisdom develops when the **fundamental principles** underlying patterns that represent knowledge are understood. Even more so than knowledge, Wisdom tends to be self-contextualizing. Wisdom is an extrapolative and non-deterministic, non-probabilistic process. It draws upon all the lower levels of the understanding hierarchy, and specifically upon special types of human reasoning (creative, innovative etc.) [21]. Unlike the previous levels, it may ask questions to which there are no easy answers, and in some cases no answers at all.

Ackoff [2] asserts that it is the difference between efficiency and effectiveness that differentiates Wisdom from the lower levels in the understanding hierarchy. Data, Information and Knowledge primarily contribute to efficiency, while Wisdom is required to assure effectiveness. Data, information, and knowledge have value in that they facilitate the process of pursuing goals, objectives and desired outcomes. Wisdom is used to choose the **right** things to pursue and thus the effectiveness of the choice takes into account the value of the outcome [4].

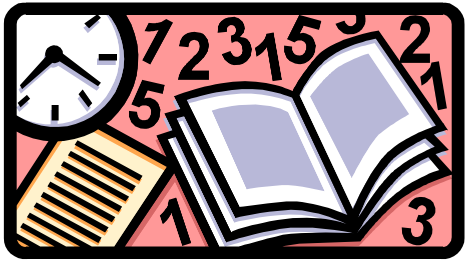
Wisdom is knowledge organized into **principles** we use to reason, discern or judge. Wisdom is **conditional** in nature and may provide answers to questions about **when** and **why** to apply procedures and the **contexts** and **circumstances** under which it is **appropriate** to apply and transfer procedures [3, 4, 21]. To understand wisdom one must **understand the principles** that underlie the knowledge that comprises it.

Wisdom exemplifies principles, insights, morals, values and archetypes [21]. Both Ackoff [4] and Bellinger [21] argue that wisdom may be a purely human state and that computers do not posses today and may never posses. We do not necessarily agree with them, and there are a few examples of IT employing Wisdom. A computer analogy might be IBM's Deep Blue Chess software acquiring wisdom through experiential learning. Another computer-based example is the system LaRiviere created to leverage the collective wisdom of technical support representatives [50]. When a call comes in, the technical support representative can enter information about the "symptoms" of the problem and the system determines possible diagnoses and solutions based on jointly stored solutions and problems [50].

IS and the KMS Hierarchy
Our adaptation of Tobin's and Ackoff's hierarchies is a useful conceptualization of the levels of understanding and can be mapped very well to IT used in organizations. We now present IT task examples that map to different levels of the understanding hierarchy.

Manual Searching and Browsing
In this example searches are visual by scanning and/or manual by thumbing through reference materials, and search result context is developed manually by users. Figure 5 illustrates that the majority of material is in the form of data and users have to spend time creating relations and patterns to generate useful information or knowledge. Users must provide a specific context in terms of both search criteria and during results analysis.

Figure 5. Manual Searching and Browsing



Computer technology may not be entirely lacking, however the functionality for deriving information and knowledge from data is severely limited. One computer application would be spreadsheets that start out containing data. Another computer example is the file structure that users build as they create directories and subdirectories. Manual searching and browsing can be done at several different levels within the understanding hierarchy depending upon the specific nature of the task and the IT used to support it.

Technology Supported Searching and Browsing
In this example organizations employ IT to store meta-data about their data, information and knowledge online. Both user-directed and automated keyword searches are employed. The majority of material is in the form of data and information and users employ technological aids to assist them in building relations and patterns to generate useful information or knowledge. At this level searches are aided by IT that presents the data through relationships and structures such as linear lists, relevancy or date sorting, or Self Organizing Maps (SOMs) [25] created through neural

networks. Figure 6 depicts an example of search results from an internet search engine that are organized based on keywords. Technology supported searching and browsing can be done at several different levels within the understanding hierarchy depending upon the specific nature of the task and the IT used to support it.

Figure 6. Sample Keyword Search Results

1. Groupware Central - . Our goal is to provide information
is currently under construction. If you would like to help u
http://www.cba.uga.edu/groupware/groupware.html

2. The **Groupware** Survey - Given that the definition of **Gro**
consider to be **Groupware** or included in the **Groupware**
http://members.tripod.com/~Groupware_Survey/survey.html

3. CSCW &**Groupware** Index - a highly comprehensive and a
http://ww2.usabilityfirst.com/usability/cscw.html

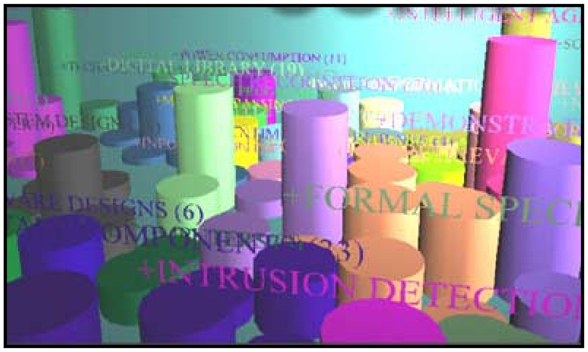
4. **Groupware** - The Changing Environment - **Groupware** is
collaboration. **Groupware** includes E-mail, Electronic Mee
http://www.collaborate.com/publications/chapt_toc.html

Visualization may begin to play a role at this level. Here the IT aides assist in providing context through semantic analysis and through structured results presentation.

Sensemaking

With sensemaking IT is used to help make sense out of data, information and knowledge automatically. Searches may be user-directed, system-directed or fully automatic versions of best practice sophistiated AI techniques. Search results may appear as contextually specific category results and as textual or symbolic models to explain relations and patterns for the user through automated briefing reports, concept Spaces, Self Organizing Maps (SOMS) and situation summarizations. These sensemaking models are designed to focus the attention of the user on important relations and patterns based on stored or system-derived knowledge. Figure 7. presents a 3D SOM in which users can see patterns among the data as they fly through the virtual model.

Figure 7. A 3D SOM Virtual Fly-Through Model

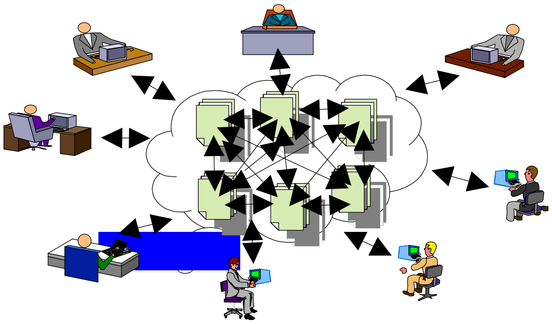


Visualization begins to play a larger role at this level. Here the IT aides assist in providing context through organizing and summarizing information and knowledge for the users. Agents also begin to play a role at this level, by performing tasks automatically for users based on stored or system derived information, and knowledge.

Knowledge Networking

Knowledge networking employs IT to share knowledge and wisdom among individuals, groups and units across the organization and even with external organizations. Strauss [84] asserts that decision-making and idea sharing are increasingly accomplished through computer networks. Argote et al. [9] assert that knowledge transfer is becoming increasingly important in organizations. Beckman [19] asserts that shared formal knowledge is a key to superior organizational performance, agility and success. Empirical research indicates that organizations that can effectively transfer knowledge between and among units are more productive and more likely to survive than those that cannot transfer knowledge as well [6, 17, 28]. Coates [26] suggests that KM need not be limited to internal sources, rather that any knowledge source, including vendors, suppliers, customers, public interest groups, government agencies and others, that might be relevant to the business, should be linked to a KM Network. This is supported by the notion in the literature that organizations can learn indirectly from the experience of other organizations [7, 44, 51]. Figure 8 illustrates a Knowledge Network model in which organizational members share data, information, knowledge and wisdom.

Figure 8. A Model of a Knowledge Network



Organizational Knowledge Networks

McGrath and Argote [58] propose a framework in which knowledge is embedded in three basic organizational elements members, tools and tasks, and within the various networks formed by combining these basic elements. Members are the human elements of the organization. Tools, including software and hardware, comprise the technical element. Tasks reflect organizational purposes, goals and intentions [10, 58]. Figure 9 presents three key organizational knowledge networks and the member relationships that comprise them.

Figure 9. Organizational KM Networks

Network	**Elements**
Social	Member-Member
Sequence of Routines	Task-Task
Technology Combinations	Tool-Tool

[10, 58]

Knowledge Networking Challenges

This example is perhaps the least well understood and least frequently found in organizations today. Tobin [88] explains that one major component is a knowledge repository that is typically a database. However, Tobin also suggests that some organizational knowledge cannot be stored in computer databases and that in this case the repository can provide pointers to learning resources. Knowledge sharing among teams and individuals in corporations is often fraught with serious problems [8, 32, 86]. In addition, Barthelme and coauthors [14] assert that organizational knowledge evolves, much as organic systems evolve, and offer a dynamic theory of KMS evolution. Tobin [88] asserts that one challenge is to maintain the accuracy and timeliness of the knowledge repository. He also explains that the knowledge repository will not add value if it is not accessible or not used by members at all levels of an organization.

Collaborative Information Systems

There is evidence of an increasing trend toward CIS. Eom Et. al. [31] in a survey of DSS development found a growing tendency towards group-based decision systems. LaPlante [50] mentions bringing together geographically dispersed workers to collaborate on team tasks as one of four categories of KMS applications. In this section we explore collaborative technologies across the spectrum, discuss reasons why collaboration is important, reasons to add technology to collaboration and then present our collaborative systems hierarchy.

Collaborative Technologies Across the Spectrum

Collaborative technologies span the spectrum from email to Group Support Systems. Coleman offers [27] a Groupware taxonomy of twelve functional categories (See Figure 10.) While this taxonomy includes all possible applications of groupware it does little to explain the relationships between them, the overlap within the categories, nor the types of support offered by each. This taxonomy does not address the differences between tools for individual productivity, those for coordination, communication and collaboration. What is needed is a hierarchy that explains how groupware tools support different tasks and processes and different levels of constructs related to collaboration.

Figure 10. Groupware Taxonomy [27]

1. Electronic mail and messaging
2. Group Calendaring and Scheduling
3. Electronic Meeting Systems
4. Desktop Video and real-time Data Conferencing (Synchronous)
5. Non-real-time data conferencing (asynchronous)
6. Group Document Handling
7. Workflow
8. Workgroup utilities and development tools
9. Groupware Services
10. Groupware and KM Frameworks
11. Groupware Applications
12. Collaborative-Internet-Based Applications and Products

We assert that there are differences between communication, coordination and concerted effort. A number of authors seem to agree and assert that successful collaboration requires much more than the exchange of information [40, 45, 48, 76]. Borman and Williams [22] assert that mere access to additional information is not sufficient in and of itself to facilitate organizational change. They argue that the application of information within the organization needs more attention in terms of existing processes and process transformation. We believe that what is needed are customized repeatable collaborative processes, akin to the patterns of information that represent knowledge. A number of studies have shown that knowledge embedded in tasks as routines or task seuqences can be tranfered effectively between organizational units [11, 18, 35, 85].

The Importance of Collaboration

Belief in the adage "*two heads are better than one*" is evidenced in the use of collaboration in many societies; for example committees, boards, councils, and the use of juries within many legal systems [41, 79]. Research shows that group performance may often exceed individual performance. Perhaps the best-known evidence comes from Hall's [37] research with the "***Lost on the Moon***" problem. Hall found that "*When a group's final decision is compared to the independent points of view that the members held before entering the group, the group's effort is almost always an improvement over its average individual resource, and often it is better than even the best individual contribution.*"

Hill [41] analyzed experimental comparisons of groups and individuals on four dimensions: task, process, individual differences and methodology. The overall results of the review and analysis showed that "*group performance was generally qualitatively and quantitatively superior to the performance of the average individual*" [41]. Workers express the desire to work together in groups. Hall [38] found in a three-year survey of 10,277 U.S. workers from all levels of employment that 97% reported they ***need conditions that encourage collaboration*** to do their best work.

Why add Technology to Collaboration?

There are several reasons why adding technology to collaboration may improve productivity. First, research and evidence from industry shows that collaboration dominates most workers time [1, 12, 13, 24, 39, 49, 61, 70, 89, 96]. Second, workers anticipate technological changes in collaboration [62, 63]. Third, a variety of augmented collaboration support technologies [59, 60] exist that may improve productivity including 3-dimensional multi-imaging [52], Video teleconferencing [77], television/film, both technology and actual content [75] and automated Group Support Systems [66, 81]. Finally, technological innovations have been shown to improve productivity in both lab and field settings.

Panko and Kinney [71] argue that given the amount of time KWs spend in collaboration attention is justified in the area of technology support for collaboration. The 1998 MPI/ASAE Survey found that at fifty-two percent (52%) technology is the most significant anticipated area of change within collaboration [55, 63].

Substantial improvements in collaboration productivity through IT have been demonstrated through research at Claremont University, Georgia Institute of Technology, London School of Economics, Massachusetts Institute of Technology, University of Georgia, University of Indiana, University of Arizona, University of Michigan, University of Minnesota, New Jersey Institute of Technology and many other institutions [30, 33, 42, 67, 69, 72, 91, 94]. Additionally, several major corporations have invested significantly in GSS technology including American Airlines, American Express, Boeing, Dupont, EDS, The Internal Revenue Service, IBM and Procter and Gamble to name a few [29, 36, 43, 46, 56, 57, 68, 69, 73, 93]. Smith [81] points out that use of GSS technology at IBM resulted in a fifty-six percent (56%) savings in the number of man-hours.

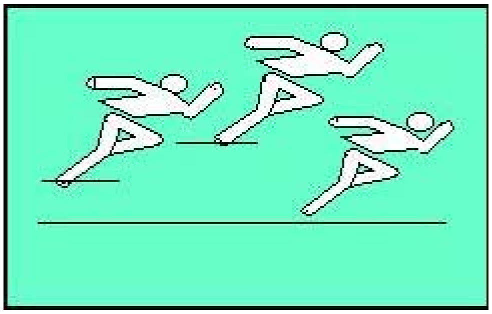
A CIS Capability Hierarchy

Over the past five years we have observed that there are actually different levels of collaborative capability that map to different types of technology. These are the **Collective, Coordinative** and **Concerted** levels of CIS capability. We describe each of the levels in terms of effort, productivity, processes, applications and team related metaphors.

Level 1 Collective Capabilities and Concepts

At this level effort toward team or organizational goals is individual and uncoordinated. Processes are individualized from start to finish. Team or organizational productivity is the sum of all members' individual performances. Typical applications are word processing, spreadsheets and graphics applications. Figure 11 depicts the team metaphor of sprinters on a track team to represent collective capability

Figure 11. Collective Capability Sprinters Metaphor



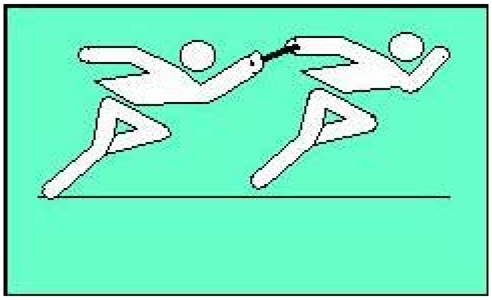
- Individual, uncoordinated effort toward shared goals
- Team productivity is sum of individual performances
- Individualized Processes - Start to Finish
- Applications
  - Word Processing
  - Spreadsheets
  - Graphics

Level 2 Coordinative Capabilities and Concepts

At this level efforts toward team or organizational goals are uncoordinated and based on either ad hoc teams and unstructured processes or coordinated teams and sequential processes. Team or organizational productivity is the sum of all members' individual, ad hoc and coordinated team performances. Typical applications include unstructured information and application sharing, video conferencing, workflow, structured team discussions and shared calendaring. Figure 12 depicts the team metaphor of a relay team to represent coordinative capability.

- Individual and ad hoc team uncoordinated effort and coordinated team toward shared goals
- Team productivity is sum of individual, ad hoc, and coordinated team performances
- Ad hoc, unstructured and coordinated Processes
- Applications

Figure 12. Coordinative Capability Relay Metaphor

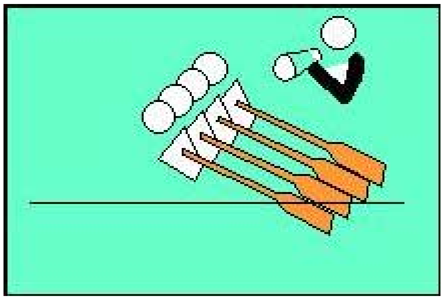


  - Unstructured information sharing
  - Application Sharing
  - Video Teleconferencing
  - Workflow
  - Structured Team Discussions
  - Shared Calendaring

Level 3 Concerted Capabilities and Concepts

At this level efforts toward team or organizational goals and processes are concerted and either simultaneous or asynchronous. Processes are repeatable and customizeable and provide attention dynamics. Team or organizational productivity is the sum of all members' individual and concerted team performances. Typical applications include Group Support Systems, Electronic Meeting Systems (EMS) and Computer Supported Cooperative Work (CSCW) Systems. Figure 13 depicts a crew team to represent concerted capability.

Figure 13. Concerted Capability Crew Metaphor

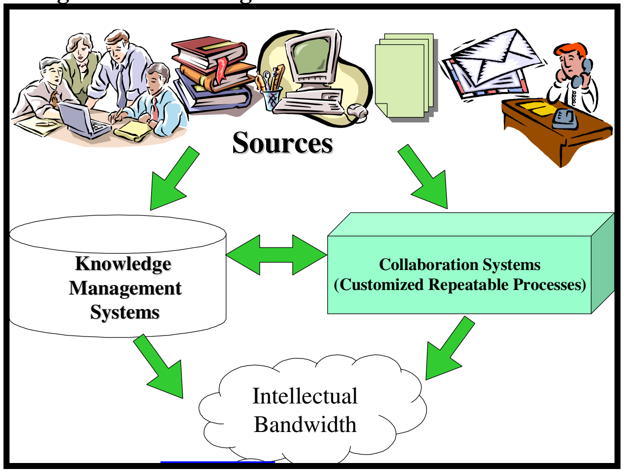


- Individual and Concerted Collaborative team effort toward shared goals
- Team productivity is more than the sum of individual and Collaborative team performances
- Collaborative Repeatable Customizeable Processes
- Attention Dynamics
- Applications
  - Group Support Systems
  - Electronic Meeting Systems
  - Computer Supported Collaborative Work Systems

An Integrated KMS and CIS Framework

We now propose an integrated KMS and CIS framework to represent the Intellectual Bandwidth (IB) of organizations. The discussion of both the KMS and CIS hierarchies makes it clear that they are becoming integrated as the technology and organization's experience through implementation matures. Figure 14 depicts that sources of data, information, knowledge and wisdom feed into both organizational KMS and CIS and the result is the elusive concept of Intellectual Bandwidth.

Figure 14. How Organizations Learn from Sources



What we term here Intellectual Bandwidth, has been defined by other researchers as Organizational Knowledge:

Organizational knowledge is the collective sum of human-centered assets, intellectual property assets, infrastructure assets, and market assets..- Brooking [23]

Organizational knowledge is processed information embedded in routines and processes that enable action. It is also knowledge captured by the organization's systems, processes, products, rules, and culture. - Myers [64]

These definitions are good conceptual notions about what organizational knowledge is, but they offer little guidance as to how to acquire, manage and transfer it among entities within the organization.

We define Intellectual bandwidth as "*a representation of all the relevant data, information, knowledge and wisdom available from a given set of stakeholders to address a particular issue.*" This includes explicit, codified data, information knowledge and wisdom that has been captured and stored in the KMS and/or CIS, as well as implicit, non-codified data, information, knowledge and wisdom that resides outside the KMS and CIS.

Together KMS and CIS can increase and leverage the amount of available intellectual bandwidth that a set of stakeholders can bring to bear to address an issue. Figure 15 presents an integrated framework of KMS and CIS capability in which the product of the two capabilities results in the amount of intellectual bandwidth available to the organization. Within this framework various collaborative technologies can be placed in terms of the level of understanding and the level of collaborative capability that they offer organizations. Within figure 15 we have placed a number of well-known KMS and CIS technologies to illustrate the relative levels of capabilities that they provide to organizations.

Figure 15. Integrated Framework of KMS and CIS

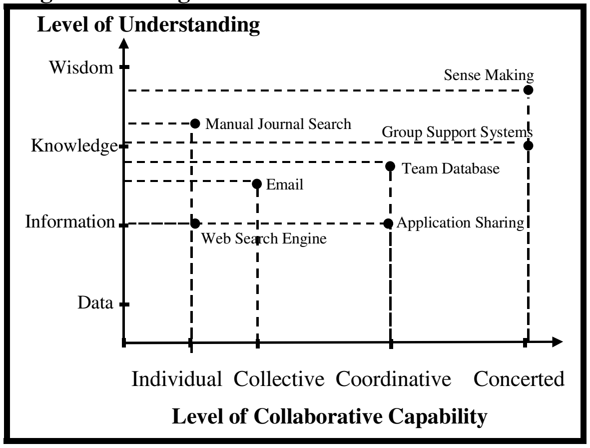
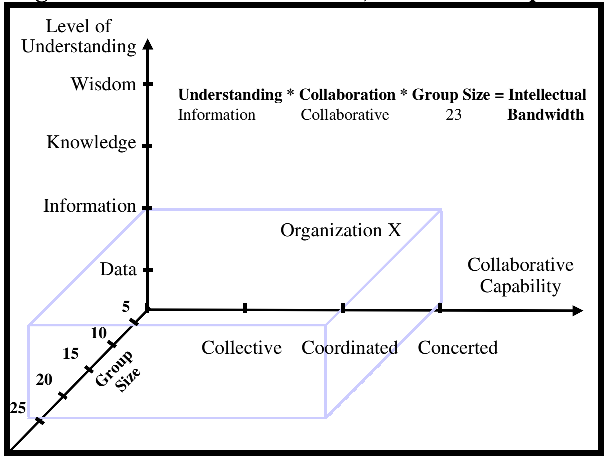


Figure 16 depicts how when KMS and CIS are integrated into an organization group size can have a multiplicative effect on the amount of available intellectual bandwidth for that organization.

Figure 16. IB = Product of KMS, CIS and Group Size



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