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INFORMATION SYSTEMS AND ORGANIZATIONAL LEARNING: THE SOCIAL EPISTEMOLOGY OF ORGANIZATIONAL KNOWLEDGE SYSTEMS

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Abstract — Current literature on organizational learning tends to be theoretically fragmented, drawing on analogies to individual learning theory or simply using organizational learning as an umbrella concept for many different kinds of organizational change or adaptation. This paper introduces a framework for the analysis of organizations as knowledge systems (Holzner & Marx, 1979) composed of a collection of knowledge processes: constructing, organizing, storing, distributing, and applying. The knowledge system framework draws heavily on the sociology of knowledge and emphasizes the social nature of each of these constitutive processes. The paper uses the framework to analyze the case of a small engineering consulting company that implemented a new information system to automate one of its core business activities: energy audits of commercial buildings. Traditional approaches to organizational learning have emphasized the ways in which information systems can lower the costs and increase capacity for search, storage, and retrieval of information. The knowledge system framework suggests a deeper level of influence, whereby information systems can also affect the objects of knowledge and the criteria for knowledge construction.

Keywords: Organizational learning, Social epistemology, Knowledge systems.

INTRODUCTION

There is an intuitive connection between organizational learning and information systems. At each stage of a system's life cycle, there are processes that evoke the metaphor of learning. Adopting a new kind of information technology, for example, has been described as a learning process (Attewell, 1992). Developing a new information system typically entails an intensive effort at identifying requirements and codifying organizational procedures and practices. Implementation often requires changes in individual skills, cognitions, and expectations, as well as changes in formal roles and structures. Once in operation, information systems typically affect the information processing patterns and capacities of an organization, a critical element in traditional learning models. Finally, maintenance of existing systems reflects adaptation to changing requirements, yet another archetypal example of organizational learning.

Despite the intuitive appeal of these examples, it is difficult to construct a systematic framework within which they can be analyzed or interpreted. This situation is characteristic of the literature on organizational learning, where many different phenomena are

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routinely grouped together under this broad metaphor (Huber, 1991; Levitt & March, 1988). The need for an integrative framework can be seen in the frustration expressed by Huber (1991, p. 108), who bemoans the lack of cumulative theory and findings. I believe this problem can be attributed, in part, to a lack of attention to the fundamentals of the phenomenon in question: the socially constructed, distributed, and embedded nature of knowledge, and the processes through which it changes.

The objective of this paper is to articulate a systematic framework for analyzing the effects of information systems on organizational learning that is grounded in the sociology of knowledge (Berger & Luckman, 1967; Bloor, 1976; Gurvitch, 1971; Holzner & Marx, 1979; Latour, 1987; Schutz, 1962). This rich and well-articulated theoretical tradition maps closely onto the phenomenon we are attempting to understand. The basic idea is to view organizations as "knowledge systems" composed of a collection of socially enacted "knowledge processes" (Holzner & Marx, 1979) which may be augmented (or impaired) by the introduction of new information systems. This provides a systematic basis for analyzing the effects of information systems, including the traditional information processing effects and the other kinds of examples mentioned above. The critical point, of course, is to move beyond the anthropomorphic metaphor of organizations as individual cognizers and treat them as social collectives that construct, organize, store, distribute, and apply knowledge through primarily social means. Viewing an organization as a social knowledge system provides a more encompassing framework within which phenomena like organizational learning can be analyzed and interpreted.

After outlining the knowledge system framework, I will use it to analyze the relationship between information systems and organizational learning in the context of a small engineering consulting company. This case is interesting because it concerns the development of a system designed specifically to embody the knowledge required for the firm's core line of business: energy auditing of commercial buildings. The question here is, how did the development and implementation of this system affect the knowledge system of the small consulting company that developed it? The framework calls attention to aspects of the case that would be glossed over in more conventional approaches to organizational learning (for example, by altering the objects of knowledge within the organization and the criteria by which new knowledge is constructed). In this way, the knowledge system framework provides a deeper and more systematic approach to the analysis of information systems and organizational learning.

THE ORGANIZATIONAL KNOWLEDGE SYSTEM: A FRAMEWORK FOR ANALYSIS

While organizational learning is a popular concept, it is rather difficult to pin down empirically. Weick (1991) argues that the traditional behaviorist definition of learning from individual psychology—same stimulus, different response—is problematic when applied to organizations. Not only is this sequence of events rare and difficult to observe, but explanations other than learning are difficult to rule out. Furthermore, many organizational systems seem geared to produce the same response to an increasing variety of stimulus (thus absorbing uncertainty and environmental variations). Fiol and Lyles (1985) also point to the difficulties involved in measuring learning, given that organizations may develop cognitive resources that are not reflected in behavior. In practice, most empirical studies treat organizational learning as synonymous with performance improvements of the kind that characterize learning curves (Argote, 1993; Epple, Argote, & Devedas, 1991). Weick (1991,

p. 121) suggested two strategies in response to these difficulties: (a) to retain the traditional definition; or (b) replace it "with a definition that is tied more closely to the properties of organizations."

This paper pursues the second strategy by emphasizing the social nature of knowledge in organizations. Knowledge is always embedded in some social collectivity and is subject to the cultural assumptions, practices, and power relations operating within that collectivity. Holzner and Marx (1979) offer an analysis at the societal level that draws heavily on the phenomenological tradition in sociology of knowledge (Berger & Luckman, 1967; Gurvitch, 1971; Schutz, 1962). Their framework seems particularly appropriate to the analysis of organizational knowledge and learning because it focuses on pragmatic knowledge that is intended to achieve a certain end within a certain time and space. Holzner and Marx (1979) identify a set of five "knowledge processes:"

1. Construction.—This is the process through which new material is added or replaced within the collective stock of knowledge. The material in question need not be "socially new" (Machlup, 1980) in the sense of being new to all humanity; it need only be new to the collectivity in question. Thus, transfer between social collectivities, such as organizations, entails some measure of construction within the recipient or "learning" organization. There are many specific ways in which knowledge can be constructed by the community and integrated into their daily practices. As we shall see, there are a wide variety of criteria that social collectives use to ratify experience as knowledge.
2. Organization.—This is the process by which bodies of knowledge are related to each other, classified, or integrated. For example, it turns out that lighting fixtures have a significant influence on the heating and cooling of commercial buildings; even high-efficiency fluorescent lights give off heat. It is not sufficient to simply construct knowledge about lighting fixtures as a separate domain; knowledge of new kinds of lighting fixtures and their thermal characteristics must be integrated into the knowledge base on heating and cooling. Establishing and maintaining these relationships as newly constructed knowledge is added is also a social process, subject to the same kinds of cultural assumptions and criteria as the construction process itself.
3. Storage.—Once a new observation or experience has passed the test and been socially ratified as knowledge, it must be stored somehow. Without storage, there is no possibility for "memory" or application. Naturally, computer-based information systems have a significant role to play here, along with paper-based filing and documentation systems, and of course, individual human memory. The effectiveness of these mechanisms as storage is always mediated, however, by social processes (Walsh & Ungson, 1991).
4. Distribution.—A critical issue in any organization is distributing knowledge to places where it is needed and can be applied. Again, computer-based information systems have an increasingly important role to play, along with paper-based systems and face-to-face social interaction. Because of their communicative function, distribution processes naturally have an important social component (Manning, 1992).
5. Application.—Unless knowledge is applied in practice, there is no possibility of obtaining the kind of performance improvement that is characteristic of our intuitive understanding of "learning." Application takes many forms, of course, but it is a necessary part of any organizational learning system. As Pentland (1992) argues, it would be difficult to make an attribution of knowledge or competence to an organization that did not produce knowledgeable or competent performances.

It should be readily apparent that these five processes are all essential parts of any effective learning process in a social collectivity. Construction, organization, storage, distribution, and application are like links in a chain; if any one of them fails, it would be difficult to make an attribution of learning. This framework emphasizes the socially constructed and embedded nature of organizational knowledge, and explicitly calls attention to its distribution. It also suggests that organizational learning need not be seen as a single, monolithic construct. Rather, it can be treated as a collection of simpler processes, each of which contributes to the overall effect. One could construe these processes as narrowly technical, lacking in social content, as would be the case if each process were somehow automated. But as Collins (1990) has argued, even the operation of simple devices like pocket calculators ultimately depends on the interpretive framework provided by the social context in which they are used. Each knowledge process entails, by necessity, some degree of social interaction, if only through the use of language.

The knowledge system framework is similar to the typology of processes described by Huber (1991) in some respects. For example, Huber's (1991) encyclopedic review of the literature identifies "knowledge acquisition," "information distribution," "information interpretation," and "organizational memory" as the four high-level processes in his typology of learning processes. Each of these (except for information distribution) is further subdivided into sub-processes. While Huber (1991) does an excellent job of categorizing published contributions, his typology of processes does not add up to a systematic framework for analysis of organizations, nor does it claim to be. It is more like a conceptual umbrella under which many diverse processes are sheltered. Huber's (1991) analysis also embodies the kind of objectivist epistemology that is common to much of the literature he reviews, where knowledge is treated as an objective good to be "acquired" (Epple, Argote, & Devadas, 1991). As a result, the social nature of the underlying phenomena gets lost in the rhetoric information processing and managerial decision making. While some authors discuss problems of sense-making (Daft & Weick, 1984) or superstition (March & Olson, 1976), the bulk of the literature seems to adopt, implicitly or explicitly, a simple objectivist epistemology. With the exception of those works informed by theories of practice (e.g., Brown & Duguid, 1991), the details of knowledge construction as a social process are largely assumed away or taken for granted.

In contrast, this framework emphasizes the socially constructed nature of knowledge and the variety of epistemic criteria that may be in use. But social processes do not cease to operate after construction; each of the other four processes is enacted by organizational members, as well, and must also be treated as problematic. The processes used to organize, store, and distribute apparently objective information are equally subject to social influence. For example, in a detailed comparative ethnography, Manning (1988) analyzes the transformative effects of information technology on the emergency calls received by two police organizations, one in the U.S. and one in England. Each police department used advanced information and telecommunications systems, but as messages crossed organizational boundaries (e.g., from the switchboard operator to the dispatcher to the squad car), their significance changed systematically. These kinds of effects are generally overlooked when an objectivist epistemology is adopted.

It is important to remember that each of these constitutive processes is, within the confines of this paper, merely a label for a broad range of specific practices that may be defined and enacted within particular organizational settings. Unfortunately, as Bourdieu (1990) points out, labeling a practice tends to objectify it as a lifeless abstraction. Thus, in an effort to reduce "organizational learning" into a more manageable set of analytical categories, one runs the risk of engaging in a kind of shell game, whereby the phenomenon of interest is pushed farther from view by a series of facile moves. The way out of this infinite regress, of course, is to present concrete descriptions of practice in specific situations. As Wittgenstein (1958) argues, practice is a kind of bedrock against which explanations of social phenomena must ultimately rest. In the case study that follows, such descriptions will be provided.

The use of the term *process* is an important aspect of the perspective taken here. The idea is that knowledge is the product of an ongoing set of practices embedded in the social and physical structures of the organization. It is meant to convey the dynamic quality of the overall system. Once constructed, however, "facts" and other modalities of knowledge take on a static, objective quality for organizational members (Berger & Luckmann, 1967; Latour, 1987). These cultural products may be embedded into tools and other artifacts, most notably computer software. When these tools breakdown (Winograd & Flores, 1986), the veil of knowledge may be peeled away to reveal the fuzzy features below. Deconstructionists have made a discipline out of such peep shows, but for organizational members themselves, facts are facts until proven otherwise. One may adopt a critical stance towards these cultural products, but organizational members generally do not, and the knowledge system framework does not. In this respect, it adopts an "emic" or insider's stance, taking cultural products at the face value assigned by organizational members (Geertz, 1983; Headland, Pike, & Harris, 1990). For this reason, it is important to consider the ways in which members make this determination.

SOCIAL EPISTEMOLOGY: KNOWLEDGE IN PRACTICE

The core of a sociologically informed approach to organizational learning must be the sociology of knowledge. Over the last two decades, our understanding of the process of knowledge formation has evolved from one that gave a privileged place to formal scientific method and "nature" as the ultimate arbiter of truth (e.g., Goldman, 1987) to a more empirically driven understanding of knowledge formation as grounded in human practice and interaction (Latour, 1987; Lave, 1988). Bloor (1976) advocates what has come to be known as the "strong programme," whose followers have conducted detailed observational studies of scientists and engineers at work. The findings of these studies suggest that even in the realm of laboratory science, knowledge is best viewed as a social construction (Knorr-Cetina, 1981; Latour & Woolgar, 1982). The critical insight is that the practices and criteria that social collectives use to ratify experience as knowledge is an empirical question that cannot be decided by philosophical argument.

Latour (1987) provides a set of guidelines for the conduct of such inquiry. Latour argues that one must follow scientists and engineers through society so that one can observe their practices. Latour's argument is based on the observation that once experience becomes formalized as "knowledge," it is increasingly treated as a black box whose contents are taken for granted. Once this occurs, the social origins of a particular fact can be difficult to trace. Hence, one must see what goes inside the black box before the lid goes on. Latour draws on examples from science (e.g., the development Watson and Crick's model of the double helix) and engineering (e.g., the design of Data General's MV8000 computer) to argue that "[t]he fate of facts and machines is later users' hands; their qualities are thus a consequence, not a cause, of a collective action" (1987, p. 259). In other words, facts are only facts if other people treat them that way. They gain and retain their status as facts based on subsequent social discourse, not based on their relationship to nature.

While some philosophers decry what they perceive as the debasement of knowledge through faulty epistemology (e.g., Goldman, 1987), sociologists have observed that there are, in practice, a variety of different criteria that social groups apply to form and test their beliefs in discourse and interaction. Holzner and Marx (1979) offer some examples of criteria that are often used, in practice, to justify knowledge claims.[1]

1. Ritual/superstitious. — Ritual criteria for truth are commonplace in daily life, and are even quite common in high technology settings. Barley (1988) identified a variety of problem-solving routines used by radiological technicians that appear to be purely ritualistic, reflecting a blind faith that a given action has a beneficial consequence (e.g., banging on a machine in a particular way). The efficacy of such procedures need not be demonstrated; they are part of the common stock of knowledge because they are simply "what is done here." Appropriate performance of the ritual may signal group membership, as much as anything else (Collins, 1981).
2. Authoritative. — Authoritative criteria are also quite common, as in the example of religious beliefs. The justification for a great many beliefs in our society is simply that a trusted (or respected, or perhaps feared) individual says that it is so. Among children, that is a major source of knowledge. Authoritative sources are foundation upon which both public education and propaganda gain their power (Cialdini, 1988).
3. Pragmatic. — Practical experience is, of course, a major source of knowledge in any social group. Success is the critical test for many kinds of knowledge. Engineering knowledge, for example, has traditionally been based on pragmatic criteria, as have many medical procedures. Mulkay (1984, p. 92) offers the example of a British surgeon using strips of paw-paw fruit to clear up a post-operative infection after a kidney transplant. The doctor could not explain *why* the tribal remedy worked, but he had seen it work before; his knowledge of this remedy was pragmatic.
4. Scientific. — Scientific criteria for truth have a strong grip on the minds of many scholars and academics, as reflected in the dominance of successive paradigms of scientific inquiry. Particular standards of proof vary among fields, but the acceptable standard of rigor and reproducibility generally goes beyond a simple test of efficacy. One crucial difference between scientific criteria and "merely" pragmatic is that scientific criteria are explicitly intended to be objective or value-free. The resulting "truths" are believed to be independent of the particular interests or biases of the individuals involved in their production because they reflect "nature" (Latour, 1987). Pragmatic criteria, in contrast, are explicitly subjective and value-laden. To say that something "works" implies that it works well enough for the purpose at hand, which may vary from time to time and from observer to observer. Scientific truths, on the other hand, are believed to transcend time, space, and culture.

[1]My point in mentioning these categories is to call attention to their diversity, not their purity, and to emphasize that as an empirical matter, people use many kinds of justifications for their beliefs. One of the key findings of the strong program on sociology of scientific knowledge is that so-called scientific criteria are, as a practical matter, rife with pragmatic, authoritative and ritual criteria (Hacking, 1992; Woolgar, 1988). Turkle and Papert (1992) provide an alternative view of epistemological diversity.

Epistemic criteria act as rhetorical resources for members of an epistemic community to debate each others' knowledge claims. Scientists conduct such debates through journals and professional meetings, while engineers conduct them through design reviews and acceptance tests. Regardless of the particular setting or mode of discourse, these debates take place in the context of the theories, hypotheses, technologies and practices that permeate the community (Hacking, 1992); in this respect, epistemic criteria are but one of many factors that influence the status of a knowledge claim. As Latour (1987) argues, the status of a particular piece of knowledge depends on the outcome of these debates over time. Depending on the community in which the debate takes place, certain criteria may be more persuasive to members than others. As the debate converges, however, the issue will become more or less settled and take on the character of a black box (Latour, 1987).

The heterogeneity of organizational cultures makes it difficult to assume a single criteria for all members (Martin, 1992; Schein, 1985). This is one of the key issues involved in translating Holzner and Marx's (1979) framework to the organizational level. While they assumed a relatively homogeneous community of professionals, in a complex organization, various occupational or functional groups will not necessarily share epistemic criteria (Van Maanen & Barley, 1984). For example, different occupational groups (e.g., engineering vs. marketing) may accept different sources as authoritative or engage in different rituals. In this situation, the knowledge distribution process might be impaired as constituencies question each other's criteria. Thus, a complex organization must be treated conceptually as a collection of overlapping knowledge systems, each of which may correspond to a larger epistemic community, or to some functional or geographic area.

In the case study that follows, we will see how the implementation of a new information system brings members of different occupational communities into the organization. The case provides the opportunity to examine each core knowledge process over time and to examine the ways in which those processes were shaped by the introduction of new technology. It also provides an opportunity to illustrate each of the processes with a concrete example. I will argue that information systems can affect the critical processes of knowledge construction and organization by changing the epistemic criteria used in knowledge construction and by changing the content of the material that emerges from the creation process. To the extent that this is true, the effects of information systems can be deeper and more pervasive than traditional models of learning would suggest.

OVERVIEW OF THE CASE

The case presented here is drawn from 10 years of experience working at (and later consulting to) a small engineering consulting company that I will call EnerSave (a pseudonym). My involvement at EnerSave started in 1981 when I was hired as an HVAC engineer[2] to perform energy audits of commercial buildings. The nature of this work will be described in more detail below. I was soon asked to help with a software development project that occupied my time for the next 3 years. During this time, I designed and wrote software. Since it was a small organization, I also became involved in documentation and end user training. I left EnerSave in 1984, but I periodically returned to help with software

[2]Heating, ventilating, and air conditioning (HVAC) is a common category of engineering specialization and employment.

maintenance and the implementation of new features until 1991. Thus, in terms of level and duration of involvement, I have a considerable experience base with this case, but because my role at the time was exclusively that of participant, I am an observer only in retrospect. I have notes and archival records from the time period in question, including design documents, notes from meetings, examples of audit reports, input forms, and other artifacts of the work process. Although they were not collected for the purposes of this research, these notes provide important reminders and have helped me to reconstruct the events I describe here. Knowing the limitations of my own memory, however, I have limited the scope of my assertions accordingly. Naturally, there are many aspects of the case where more systematic data could be used to deepen the analysis.

EnerSave was founded in the mid-1970s to provide a range of energy conservation related consulting services to commercial businesses, public utilities, and government. The energy audit business started to boom after the OPEC oil embargo and EnerSave was there to take advantage of this opportunity. Energy costs soared, and the United States federal government began to offer energy tax credits, suddenly making conservation into an attractive investment. During the 10-year period between 1981 and 1991, EnerSave grew from a 30-person engineering and consulting boutique with one office, to a 600-person organization with offices in several major cities across the United States.

A significant part of their initial growth can be attributed to the development of a knowledge-based software application, which I will call EnCAP (EnerSave Commercial Audit Program). This program "encapsulated" their specialized engineering knowledge and helped them deliver it at low cost to a large number of customers. By substituting high-school educated technicians using this sophisticated software for college educated engineers, EnerSave could provide a high-quality engineering analysis that would formerly have cost many thousands of dollars for only hundreds of dollars. Later, they implemented a variety of other systems to help utilities deliver a wide range of energy conservation services to their customers.

From a practical and economic standpoint, the program was a success. It was used for over 10 years by EnerSave personnel and by utilities across the United States to complete tens of thousands of audits. The question that will concern us here is, how did the development and implementation of this system affect the knowledge system in this organization? How can we compare the knowledge processes at EnerSave before and after the introduction of EnCAP? What implications does this case have for the implementation of other kinds of systems in other contexts?

Manual energy auditing: The good old days

An energy audit is like a financial audit: it provides a detailed analysis of the inputs and outputs of a system. But instead of an accounting system, the object of inquiry is an energy system. To perform an audit, one collects detailed information about the existing condition of all major energy systems in the building: lighting, heating, cooling, hot water, and the building envelope (walls, windows, and doors). In addition, for many kinds of commercial facilities, there may be large electric motors, air compressors, drying ovens, and so on. An important objective of energy auditing is to identify opportunities for cost-effective conservation measures, such as high-efficiency lighting or improved insulation. Thus, while data is being collected, the energy auditor typically starts to formulate ideas about what kinds of improvements are possible. As the analysis of the facility proceeds, the auditor develops these ideas into detailed recommendations about how to improve the energy performance of the facility, including costs, benefits, and payback periods.

Formerly, this task required fully trained engineers. Typical audits required a few weeks of engineering time, plus word processing support to create the report, which was often over 100 pages, including figures. As a result, these reports cost a minimum of several thousand dollars, and $10–20,000 was common. At these prices, however, only rather large facilities with high energy costs would typically engage an engineering firm to audit their energy use and make recommendations.

The manual audit process was customized to the particular needs of each customer, but there were certain aspects of the firms methodology that were typically applied to every audit. For example, the engineers performed an overall energy balance on the facility to determine which end uses (such as lighting, heating, cooling, etc.) consumed what fraction of the total energy bill. Likewise, certain kinds of recommendations (such as replacing incandescent lighting with fluorescent lighting) were very common. As a result, the engineers had accumulated a library of standard analyses and recommendations. The analyses were sometimes coded into small computer programs written in BASIC and run on a time-sharing system (personal computers and spreadsheets were not available yet). The recommendations took the form of "boilerplate" text stored in a WANG document processing system that could be modified to fit into the client's overall report. Even when an analysis had to be performed by hand, the "working papers" and supporting calculations from prior audits served as templates that could be re-used in subsequent audits. In these ways, the engineers in the firm accumulated experience and improved the efficiency of their services.

Automated energy auditing: A brave new world

In the early 1980s, state regulatory boards started to realize that it was cheaper and better to conserve energy than to build new capacity. Electric and gas utilities across the United States were mandated to provide energy audits to their residential and commercial customers as a means of encouraging conservation. In some cases, the audits were offered at a very low cost, while in other cases, the utilities were allowed to incorporate the cost of these audits into their rate base. In either case, this regulatory action created a substantial demand for cheap, effective energy audits.

In response to this opportunity, the management at EnerSave conceived the idea of an "automated audit." Their objective was to replicate their current, largely manual process, so that it would take less time and could be performed by people with less training. Their initial idea was to take a collection of analysis programs they had developed in BASIC (e.g., for heat transfer, discounted cash flow, etc.) and combine them into one large program. The absurdity of this proposal soon became apparent. To begin with, the programs shared no common data structures or interfaces and could barely be maintained in their current form. The idea of basing a large application on such a shaky foundation was quickly dismissed.

When it became clear that a more coherent development approach would be required, several young engineers were enlisted to write a set of "modules," one for each major area to be addressed in the audit. They worked in conjunction with some of the more experienced auditors to encode the relevant knowledge about each building energy system, such as lighting, heating, and so on. Each module would read its input, perform the necessary computations, and then prepare an intermediary file for further processing by a text formatting program called Scribe™. The text formatting program allowed the developers to make extensive use of a library of several hundred customizable paragraphs with large numbers of textual "fill-ins" that created the impression of a fully customized report. Indeed, the new reports were often 50–60 pages, very similar in outline and appearance to the hand-produced reports.

Differences in the knowledge system over time: Effects of a new information system

To interpret the changes in the knowledge system over time, it is useful to break the case into three distinct time periods: before, during, and after the implementation of the automated audit system. For each time period, it is instructive to consider each aspect of the knowledge system: the members of the various occupational communities represented within the organization, the object of knowledge, the epistemic criteria, and each of the five knowledge processes (constructing, organizing, storing, distributing, and applying). To highlight the effects of the system and its implementation, I will examine each of these categories over time. Table 1 provides an overview of the differences, each of which is described in more detail in the following sections.

Changing epistemic communities. The implementation of the automated auditing system affected one of the key components of the organizational knowledge system: the epistemic communities represented in the organization. As outlined in Table 1, during the manual auditing period, the organization consisted mainly of engineers and typists. The engineers collected data, performed computations, and made recommendations, while the typists prepared the reports from the templates available on the WANG word processing system. During system implementation, a new kind of member was introduced to the organization: the programmer. These individuals (myself included) were mainly recruited from the existing pool of engineers; two were hired especially for the project. Later, as the system was completed and rolled into production, the community of programmers shrank, while the community of technicians using the program began to grow rapidly in locations all over the country. To supervise this workload, it was necessary to add administrative staff, as well. Thus, the implementation of the system changed the basic membership of the epistemic community to include individuals whose background and training was very different than the traditional engineers. As the participants changed, it created the possibility that their approach to knowledge construction (and the other knowledge processes) might change, as well. This is an area where contemporaneously collected data could be especially valuable because it is difficult for me to assess the impact of these changes retrospectively.

Changing objects of knowledge. The literature on organizational learning generally assumes that objects about which knowledge is being accumulated are relatively constant. For example, organizations learn about "the environment," "the competition," or "production processes" (Huber, 1991). The specifics change, but the domain of relevant knowledge is assumed to remain the same over time. In the implementation of EnCAP, this assumption is clearly incorrect. During the manual auditing phase, the objects of knowledge were basically building energy systems: lighting, heating, cooling, etc. I remember conversations in the hallway outside my office, where people would discuss the relative benefits of different lighting systems, heat exchangers, and so on. Engineers took a great deal of pride in having a working knowledge of these systems.

During systems development, however, the new members of the organization, including myself, were overwhelmingly concerned with issues of software design and implemen-

Table 1. Summary of Changes in the Knowledge System by Time Period

	Manual Auditing (1976-1981)	System Development (1981-1983)	Automated Auditing (1983-1993)
People Involved	Engineers (10-20) Typists (3-4)	Engineer/Programmers (6)	Programmers/Engineer (2-3) Technicians (several hundred) Administrators (5-10)
Primary Domain	Building energy systems: Lighting, heating, cooling, etc.	VAX/VMS and languages	Completed application (EnCAP)
Epistemic Criteria	Authoritative (little feedback about results)	Pragmatic (immediate feedback about results)	Authoritative Ritual/superstitious
Knowledge Processes			
Construct	Trade associations and vendors are an authoritative source of methods and specifications Individual engineers gain experience in specific situations	Algorithms invented to mimic simplified engineering analysis Naming: Data structures, control structures, files, programs, libraries, etc.	Technicians learn necessary workarounds Administrators identify new requirements Programmers rediscover how system works during maintenance
Organize	Informally organized; indexed by individual engineers and projects	Energy auditing divided up into "modules" and "forms"	Organized around application artifacts: "forms" and "reports"
Store	Worksheets kept by individual engineers Old reports in company library WANG "boilerplate" for use by typists BASIC programs for use by engineers	Embed algorithms into design of forms, modules, and measures Systems adopted for code management, version control, testing, etc. Documentation written	New (or modified) algorithms coded into the application "Gurus" develop "tricks" to achieve desired results "Setup" files used to store basic program parameters and output text
Distribute	Trade publications Direct sharing	Frequent informal meetings among programmers	Application used in-house and licenced to large public utilities—includes training and documentation New features made available to all
Apply	Engineers use knowledge for next audit	Programmers embed engineering algorithms in code	Technicians use tricks to get results

tation. The objects of knowledge became VAX/VMS (the operating system for the host computer), the PL/1 programming language, as well as the data structures, file structures, and architectural features of the rapidly growing application. This was naturally a period of intensive learning, but there is little doubt that the subject matter was completely different than in the prior period. Finally, as the finished EnCAP application was rolled out, the focus of learning turned away from the internal features of the software and its construction and towards the external features of the software and its use. As Latour (1987) would predict, the system progressively became a black box and the new object of knowledge was the application itself: inputs, outputs, bugs, features, and workarounds.

Once the application was in use, members of the community learned about the software rather than learning about energy auditing per se. A great deal of knowledge that was created at EnerSave since the introduction of EnCAP concerned details of how to use the program: how to "fool" it to get the recommendation you want, how to work around various bugs, and so on. While this knowledge was clearly necessary to accomplish audits under the new system, it was idiosyncratic to the EnCAP audit process. Thus, in addition to embedding existing knowledge about auditing and commercial buildings, the software required the construction of new knowledge about EnCAP itself.

Epistemic criteria. The literature on organizational learning generally assumes that the criteria for knowledge never change. A scientifically oriented community, for example, is assumed to stay scientifically oriented. Like the objects of knowledge, epistemic criteria are taken for granted as an unchanging feature of organizational learning. Once again, this case illustrates the weakness of this assumption. During the period of manual auditing, the key epistemic criteria were primarily authoritative. As engineers, the staff at EnerSave relied heavily on published sources of information concerning the performance of particular products (for example, the energy consumption of a particular kind of lighting fixture) as well as the appropriate equations for computing energy savings. These were treated as authoritative sources, and were sometimes cited in client reports or in supporting computations.[3] There was very little opportunity to confirm the accuracy of these computations, however, because clients were rarely interested in paying for follow-up studies. One could, in principle, have applied pragmatic or scientific criteria for knowledge, but given the constraints of the business and the interests of the customer base, that was not possible. Recommendations were based strictly on authoritative sources.

During system development, a very different kind of criteria came into force. While authoritative sources were often consulted (e.g., concerning the syntax of a particular command), the basic criteria was strictly pragmatic: does this work? As with many development projects, deadlines made pragmatic criteria particularly salient. The objective was to create code that worked, whether or not it was elegant or efficient. Also, we were often confronted with situations where it was unclear why something did or did not work. Trial and error was a common, pragmatic approach to resolving these difficulties.

Once the implementation was well under way and automated auditing was in use, the epistemic criteria underwent a second transformation. There was, to some extent, a swing back toward authoritative sources, but different sources than before. The translation between manual practice and automated procedure was, in many cases, quite radical. As a result, the engineers who were masters of the manual practice were often helpless to explain the automated results. When people wanted to know why an audit turned out the way it did (e.g., why turning down the thermostat didn't seem to save much money), they had to consult the software engineers or one of a number of individuals who understood the workings of the program. These "EnCAP Gurus" (who were often software engineers or technicians with substantial automated auditing experience) became the authoritative experts, rather than published technical references or the mechanical engineers.

In addition, ritual/superstitious criteria became much more prominent. As with any complex product that is hastily developed, there was a tendency to "forget" why things worked the way they did, and the documentation for EnCAP was often sketchy. Many of the algorithms were based on rules of thumb of engineers who no longer worked at Ener-

[3]Like financial auditors, the engineers at EnerSave routinely prepared "working papers" that contained the computations that supported their analysis and conclusions. These working papers would include citations to the manual or product specification guide, so that others could retrace their steps, should the need arise.

Save, so it was sometimes difficult to pin down exactly why things worked the way they did. In the absence of authoritative sources, it became natural to adopt conventional (ritual) understanding and practices concerning the use of the software.

Constructing. Changes in the membership of the epistemic community, the objects of their knowledge, and their epistemic criteria have enormous consequences for the process of knowledge construction. During the period of manual auditing, knowledge creation was largely accomplished external to the firm, through trade associations, vendors, and other authoritative sources of analysis methods and product specifications. These would then be imported into the organization as individual engineers gained experience in specific situations that required them to consult these authoritative sources.

During system development, of course, the process of knowledge construction was very different. A major effort was devoted to creating algorithms to perform simplified versions of engineering analysis (e.g., lighting design). A major problem in designing an automated audit was how to account for the enormous variety in HVAC, lighting, and other building energy systems and to do so in a simple, easy-to-input format. The process of cataloging and categorizing equipment was a crucial piece of knowledge construction for the design team. Through this process, they literally defined the universe of objects the system could recognize. At the same time, there was also an ongoing effort to construct appropriate data structures, files, programs, and libraries, as well as a set of tools for debugging, testing, and managing the software development and maintenance process itself.

As mentioned above, automated auditing evoked yet another round of knowledge creation, but in a different domain. Technicians constructed workarounds necessary to achieve the results they wanted. There was a great deal of knowledge constructed concerning the everyday use of the program. "Gurus" developed "tricks" to achieve desired results, such as fudging certain input codes that they knew would not appear in the output, but that would influence the results of the computations in the direction they desired.

In addition, the program needed to be maintained and enhanced over time. Administrators struggled to identify new requirements for clients and to translate those into specific program features. For example, cooling systems in Florida are very different than those in the Northeast, and the program needed to accommodate these differences before it could be used by public utilities in Florida. These kinds of changes necessitated the creation of similar kinds of knowledge as the original development. But the special problems of modifying an existing system and customizing it for various clients forced the programming staff to create new kinds of testing procedures and systems for releasing multiple versions of the "same" product.

Organizing. During the period of manual auditing, the organization of new knowledge was handled primarily through the trade manuals and new product documentation that arrived periodically at the office. There were walls lined with bookshelves containing reference material on furnaces, cooling systems, industrial equipment, and other technical reference material. In addition, each engineer had a small library of his or her own, with a similar collection of more frequently consulted references. Consistent with the arguments of Holzner and Marx (1979), the organization of knowledge within this occupational group was guided by the structure of the larger engineering community of which they were members.

During system development, this process was affected in two ways. First, a new occupational group (the programmers) entered the organization, bringing with them a whole new set of materials and concepts. The programmers group needed their own process for organizing knowledge about the domain of systems implementation. Second, and perhaps more important, the systems development process imposed a new organization on the traditional domain of building energy auditing. Energy auditing was divided up into "modules," each of which had a "form" for data collection and data entry. Data about buildings needed to be streamlined and structured so that it could be analyzed by standard algorithms. The performance parameters of heating and cooling equipment, lighting fixtures, and so on, had to be distilled into a uniform set of parameters that could be entered into a "setup" file. Similarly, data concerning the weather conditions for each location where the program was to be used needed to be collected and structured appropriately. The process of organizing the open-ended libraries of reference materials into specific forms, fields, parameters, and algorithms was essential to the operation of the program.

Once automated auditing became routine, these structures imposed by the software dictated a local organization of knowledge that was far narrower than in the field at large. New products could be added to the system only if they could be squeezed into an existing field. In rare instances, if a new client was adamant and willing to pay for the changes, new fields could be added. But the structuring effect of the input forms (and the algorithms behind them) created a very specific set of possibilities for incorporating new knowledge about building energy systems.

Storing. Under the system of manual auditing, there were many mechanisms in use that stored knowledge of various kinds. For example, there were worksheets kept by individual engineers that outlined their computations on a particular audit, as well as old reports in company library. These reports were also available on the WANG word processing, and could be used to provide "boilerplate" for the support staff to customize and include in new reports. On a more abstract level, there was also a collection of BASIC programs for use by engineers that had been written on a mainframe time-sharing system. These programs were usually written on an *ad hoc* basis as the need arose and anything new that came along was simply added to the library. By and large, these storage mechanisms were a natural by product of the work. No special steps were needed to create these forms of memory.

During system development, there was the usual effort to embed this substantive knowledge into the design of forms, modules, and so on, as described above. These were stored, then, within the growing body of PL/1 code and associated documentation. By contrast with the manual system, these storage processes required enormous amounts of highly specialized work. In a sense, the firm was explicitly investing in stored knowledge in the form of software. To keep track of the rapidly growing system, the developers instituted a set of procedures for code management, version control, testing, and release. These procedures embodied many of the details of how the system was configured, maintained, and administered. Thus, software was used to embody both substantive knowledge about auditing and operational knowledge about the system itself.

Automated auditing institutionalized the use of the software as a vehicle for storing knowledge. New (or modified) algorithms could be coded into the application as new kinds of energy conservation options became available, for example. "Setup" files were used to store basic program parameters, such as weather conditions, and the library of "boilerplate" text. Automated auditing also gave rise to the possibility of collecting a database of audit results. When audits were conducted manually, the results were simply stored on a shelf; there was little motivation to collate them into a single source that could be processed efficiently. It is questionable whether such a distillation would have been meaningful, in any event, since the audit reports contained a wide variety of different and often creative recommendations from the engineers. But the automated audit program created, as a natural byproduct of its operation, a database record containing essentially all of the inputs and outputs. When the audit process was "informated" (Zuboff, 1988), a new form of storage became both possible and necessary.

Distributing. Within the small group of engineers conducting manual audits, the system of knowledge distribution was largely through informal, face-to-face contact. The engineers shared office space, so it was very easy to ask questions. The kinds of moves that Pentland (1992) identified were also used within this group to get help on some problems and give away others. The engineering group could also access library materials directly, thereby sharing and distributing the materials they contained. During system development, the programmers used a very similar process for distributing information. Work spaces were close together, so face to face contact was simple.

Automated auditing, once it took hold, necessitated a very different kind of distribution process. The main reason was that the community of individuals involved was no longer housed together, and quickly grew far too large for face-to-face communication. Distribution of substantive knowledge about energy auditing had to take place via the EnCAP software and the associated training materials. Performance characteristics of new kinds of equipment, such as heat pumps, had to be encoded into the software before they could be shared. Previously, engineers could share techniques, worksheets, and rules of thumb directly. Under the automated system, this knowledge had to be translated into a specification, approved, prioritized, coded, tested, and distributed before it could be used. Furthermore, the knowledge could be distributed outside the boundaries of the EnerSave organization to its customers, the electric and gas utilities.

Applying. In manual auditing, the application of knowledge was accomplished as the engineers performed computations and prepared their recommendations. To do so, engineers drew upon the resources mentioned earlier (manuals, prior audits, and each other). Typists assembled the final document for the clients, who might or might not actually implement the recommendations. The responsibility for following through rested with the client.

During system development, knowledge application took a different form because the object of the activity was so different. Rather than producing energy audits directly, the programmers were responsible for producing software to produce energy audits. As mentioned above, the knowledge and artifacts necessary to accomplish this task were quite different than those needed to produce an energy audit. But perhaps more important, the criteria for successful application were different, as well, because the software had to produce reasonable results over a wide range of different input data, while a manual audit was specific to a given set of facts about a particular building. A successful implementation required, in some sense, a higher standard of performance than an individual audit because it had to handle a broader range of cases. As with manual audits, the responsibility for actually implementing conservation recommendations rested with building owners.

Automated auditing brought yet another regime of knowledge application. Applying the algorithms embodied in the EnCAP program required a different set of skills, as described above. Technicians needed to know how to identify equipment and possible improvements, and then the program would take over and complete the computations and the details of the recommendation. As mentioned above, technicians often used tricks to get results they wanted from a program they did not fully understand. The end result (a completed audit report) was similar in form and content to the manual audit reports, but the application of technical knowledge about commercial buildings occurred through a very different process. This difference was a natural product of using an automated tool rather than performing the computations and producing the audit report manually.

DISCUSSION

To help the reader evaluate the strengths and weaknesses of the knowledge system framework, it is useful to compare it with some of the main themes in the large and growing literature on organizational learning. Rather than attempting to review and synthesize all of this literature here, it is more useful to extract certain key dimensions for purposes of comparison. Table 2 outlines four key themes in the organizational learning literature and their interpretation in the knowledge system framework. Each of these themes is discussed in more detail later.

Locus of learning: Individual versus organization

The literature on organizational learning generally distinguishes between individual and organizational learning (e.g., Argote, 1993; Carley, 1992; Fiol & Lyles, 1985; Hedberg, 1981; Levitt & March, 1988). Some authors (e.g., March & Olson, 1976; Nonaka, 1994) make the relationship between individual and organizational learning explicit, while others tend to focus on the organization as the unit of analysis (Lant & Mezias, 1992). In contrast, the knowledge system framework downplays the importance of individual learning in favor of an explicitly social conception of knowledge. What a single individual "knows," in short, is of little value to anyone until it has been socially ratified in some way. The position is similar to that of Attewell (1992, p. 6), who argues that: "The organization learns only insofar as individual skills and insights become embodied in organizational routines, practices, and beliefs that outlast the presence of the originating individual."

Certain individuals, such as higher level managers, may hold sufficient authority within the organization to dictate and enforce the legitimacy of their own beliefs. Legitimation and authority are obviously essential aspects of knowledge construction (Latour, 1987) and may be influential in the organizational learning effects associated with executive succession (Virany, Tushman, & Romanelli, 1992). This perspective helps call attention to the explicitly social dimension of knowledge distribution, as well. For example, Pentland's (1992) study of software support hot lines revealed that solving customer problems depended on the ability to distribute knowledge among the group (e.g., by getting help).

Table 2. Key Themes in Organizational Learning Literature

Theme	Knowledge System Interpretation
Locus: Individual or organization	Locus is social interaction; purely individual level is not very meaningful
Level: Operational or strategic (single- or double-loop)	"Level" of learning is a question of content; it is not a separate process
Source: Experience (internal) or example (external)	Parallels the distinction between knowledge construction and knowledge distribution
Persistence: Short or long term	Failures of long-term memory result from failures of storage or distribution, as well as changing relevance

Socially enacted knowledge distribution processes allowed members of the organization to collectively solve a stream of problems that no individual could have solved alone. It is reasonable to hypothesize that in situations where specialized knowledge is unevenly distributed, enhancing distribution processes (for example, via email) would be an effective means of improving organizational performance.

In the EnerSave case, before automation, there were many instances where a single engineer would learn about a new kind of system (for example, a new kind of boiler) and share it with others. Until shared, however, it is hard to imagine calling that engineer's learning organizational. After automation, individual learning had to be filtered through a software maintenance routine (designing a new feature, coding and testing) to make the new learning available to the organization. Although I cannot document it, I find it unlikely that field personnel outside the main office would have been able to initiate such learning. Thus, the locus of organizational learning that could enter the knowledge system was probably narrowed by automation.

Levels of learning: Operational or strategic

The level or kind of learning is another key theme in the organizational learning literature. Argyris and Schon's (1978) influential distinction between single- and double-loop learning can also be thought of in terms of operational and strategic learning. Lant and Mezias (1992) make a similar distinction, labeling the levels "first order" and "second order." Single-loop learning involves the adjustments necessary to meet a given operational objective, as in the way a thermostat cycles a furnace on and off to hold the temperature in the room. Double-loop learning, however, involves deciding what the temperature should be. It is conceived of as a higher, more strategic level of learning because it concerns the definition of goals. Argyris and Schon (1978) argue that so-called "higher" levels of learning involve challenging assumptions and standard procedures.

In terms of the knowledge system framework, the main difference between these levels of learning is the content of the knowledge being constructed, organized, stored, and so on. One might hypothesize that these processes might take different forms for operational or strategic knowledge, but the framework itself is indifferent. In the EnerSave case, as I saw it, the learning was primarily operational. One can assume that there must have been a parallel change in strategic knowledge over time as the firm moved from one line of business to another, and one kind of client to another. But even within the domain of operational knowledge, the shift in content was striking.

Source of learning: Experience or example

Broadly speaking, the learning literature points to two distinct sources of learning: experience and example. Learning from experience reflects the usual strategies of trial and error, successive approximation, and so on. Following the analogy to individual learning, models of learning by experience are often built at the organizational level (e.g., Lant & Mezias, 1992). Researchers have also identified the ways in which organizations learn from very limited experience, where there is no opportunity to improve based on repeated trials (March, Sproull, & Tamuz, 1991). Often, this entails the use of vicarious experience, or stories about others' experiences. Alternatively, it may be the product of systematic transfer between subunits (Argote, Beckman, & Epple, 1990). While the distinction between experience and example can be formalized and estimated statistically (Epple, Argote, & Devadas, 1991), the distinction is less clear than it might seem because it depends on the definition of the organizational boundary. That is, examples generated within the boundary (which may be drawn socially, geographically, temporally, or in some other manner) are counted as "experience," while examples generated elsewhere are not.

Within the knowledge system framework, the distinction between learning by experience and learning by example closely parallels the distinction between knowledge construction and knowledge distribution. Members testing the value of their own experiences would be constructing knowledge, while members testing the value of other's examples could be seen as engaging in knowledge distribution. Given the potential subtlety of some of these distinctions, it seems like it might be difficult to sustain the analytical distinction between construction and distribution. Within a particular knowledge system, the process of knowledge construction can draw upon a variety of sources, including members' experiences and observations of others. Thus, in practice, it is not clear how important this distinction would really be. Construction and distribution have very similar effects: they make knowledge available where it previously was not.

At EnerSave, before and after automation, learning was primarily by experience. To my knowledge, they spent very little time assessing or analyzing how other organizations performed similar work. While there were many firms offering automated residential audits, there were very few firms capable of producing an automated audit for commercial buildings. Thus, with respect to their core operations, there were few examples to learn from.

Persistence of learning: Short or long term

Empirical studies of organizational learning (Argote, Beckman, & Epple, 1990; Darr, Argote, & Epple, forthcoming) have shown that while organizations learn, they also forget. A significant component in this loss of knowledge can be attributed to turnover in personnel (Carley, 1992; Darr et al., forthcoming). These studies have also shown that recent experiences are more valuable than older ones. Part of this effect is due to the changing nature of the environment; old skills and information may not be equally useful in the face of changing conditions. Knowledge becomes obsolete. Hedberg (1981) postulated the existence of forgetting processes and the critical importance of replacing outdated knowledge. More generally, there has been an increased interest in organizational memory (Walsh & Ungson, 1991) and in mechanisms to enhance it (Ackerman, 1993).

Questions of persistence or memory have a natural interpretation within the knowledge system framework. The storage and distribution processes are critical in maintaining the availability of knowledge to members. Failures in either of those processes could be viewed as forms of forgetting. In effect, the organization either cannot store or cannot access relevant knowledge. The problem of changing relevance, however, could be viewed more as a failure in application. When old methods are tried and no longer work, then it is the final link in the chain of knowledge processes that has broken.

At EnerSave, the use of software for storage and distribution had predictable effects: persistence was excellent, but continuing relevance could not be guaranteed. Software is an excellent vehicle for storage and distribution (and thus for long-term memory), but it tends to suffer from the problem of changing relevance for just that reason. The basic engineering computations generally retained their validity, but many of the "rules of thumb" depended on assumptions about standard construction techniques, typical system efficiencies, and so on. These factors differ from region to region, and they tend to change over time. Thus, as the context of use changed, these assumptions needed to be surfaced, examined and, if necessary, changed. In short, the software required maintenance.

CONCLUSION

The preceding analysis suggests that many of the theoretical issues developed in the literature on organizational learning could be investigated as a system of knowledge processes (constructing, organizing, storing, distributing, and applying). In addition, by placing special emphasis on the social nature of the construction and distribution processes, this framework highlights the uniquely social dimension of the phenomena that is often missing from literature that draws too heavily on the individual learning metaphor. The advantage of this framework is that it decomposes the overall phenomenon into a set of smaller and more observable processes. Although these processes are distributed in time and space, they are readily identifiable and can be measured and monitored in various ways. Observability also gives rise to an important practical benefit: it lends itself to diagnosis of ineffective or dysfunctional systems. By breaking the overall phenomenon down into constituent parts, it should be easier to isolate problems and, hopefully, recommend practical improvements.

It would be a mistake, of course, to generalize too broadly from this example. The information system described here was specifically designed to embody technical knowledge and automate key aspects of a job that was generally performed by engineers. In many respects, the results reported here are understandable by-products of automating the work: the people doing the work were no longer in a position to fully comprehend or modify the tool they were using. Zuboff (1988) makes similar points concerning the work in the organizations she studied. In the extreme case, the very tool that was intended to encode the knowledge of the organization could have destroyed the organization's capacity to learn by interfering with various knowledge processes. As it turns out, in this particular case, Ener-Save seems to have maintained a strong engineering base (by diversifying into other areas besides auditing), and has maintained a strong connection to the larger knowledge system concerning energy use in commercial buildings.

Nonetheless, this example illustrates clearly that introducing an information system can have more profound effects that merely altering the storage, or retrieval, or distribution, or richness, of information. These basic information processing enhancements are well known and should, in theory, effect organizational learning. But I would argue that information systems can also change the membership of an organization, the objects of its knowledge, and its criteria for truth. These are the basic elements of social epistemology; they are the core of any social knowledge system. They are held constant in most treatments of organizational learning, thus obscuring the possibility that information systems might change them. Whether or not all of these elements belong under the umbrella of "organizational learning," information systems can change them. In doing so, information systems change the fabric of social epistemology and the backdrop against which organizations construct, organize, store, distribute, and apply knowledge.

More broadly, the example suggests a kind of technological epistemology, where our ways of knowing are mediated through machines and their maintenance. Should we be satisfied with a knowledge system where debugging and finding workarounds are a dominant mode of learning? To the extent that we view the world through a technological lens (Barrett, 1979; Heidegger, 1962), this problem becomes increasingly important. Ironically, technology may dull our senses, taking away the direct involvement, social interaction, and reflective conversation that has traditionally given rise to understanding (Rorty, 1979). The very systems that are meant to increase our information processing capabilities, thereby increasing understanding, may have the opposite effect by restricting the range of our inquiry and experience, effectively putting us in a kind of epistemological box. Whether information systems enhance or dull our senses is a difficult question to answer, but it is clearly an important question to ask.

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