Knowledge Integration in Virtual Teams: The Potential Role of KMS

By

Maryam Alavi
(Maryam_Alavi@bus.emory.edu)

And

Amrit Tiwana
(Amrit_Tiwana@bus.emory.edu)
Goizueta Business School
Emory University
Atlanta, Georgia 30322

October 2001

Please address for correspondence to the first author.

Knowledge Integration in Virtual Teams: The Potential Role of KMS

Abstract

Virtual teams are becoming a preferred mechanism for harnessing, integrating and applying knowledge that is distributed across organizations and in pockets of collaborative networks. In this paper, we recognize that knowledge application, among the three phases of knowledge management, has received little research attention. Paradoxically, this knowledge application phase contributes most to value creation. Extending communication theory, we identify four challenges to knowledge integration in virtual team environments: constraints on transactive memory, insufficient mutual understanding, failure in sharing and retaining contextual knowledge, and inflexibility of organizational ties. We then propose knowledge management system (KMS) solutions to meet these challenges. Finally, we identify promising avenues for future research in this area.

Knowledge Integration in Virtual Teams: The Potential Role of KMS

Introduction

Knowledge-based assets are now widely recognized by scholars and managers as the modern firm's most valuable resources. Performance and profitability differences among organizations can largely be attributed to asymmetries in applying knowledge-based assets to amplify organizations' existing advantages. Knowledge management and knowledge management systems (KMS) appear to be necessities for effective organizations and competitive strategy in the new millennium. Organizational knowledge management has been characterized as consisting of three overlapping processes: knowledge creation, knowledge codification, and knowledge application. A knowledge management system (KMS) is defined as an information technology (IT)-based system developed to support and enhance organizational knowledge management processes (Alavi, 2000). Among various knowledge management processes, knowledge application seems to be the most understudied process.

In this paper, we focus on virtual team environments through which firms try to tap into highly distributed sources of organizational knowledge. Through a review of communication theory, we describe how virtual teams, intended to harness and integrate distributed knowledge, create challenges to knowledge application. We discuss how several factors--including shortcomings in transactive memory, insufficient mutual understanding, failure to share and retain contextual knowledge, and inflexibility of organizational ties--constrain the very mechanisms (i.e., virtual teams) that organizations employ to integrate and apply knowledge.

Finally, we offer four specific propositions for designing knowledge management systems to eliminate or reduce these constraints.

Firms as Distributed Knowledge Systems

The basic tenet of the knowledge-based perspective is that firms are distributed knowledge systems (Tsoukas, 1996). The extent to which firms can bring both the knowledge they own and the knowledge they can access to bear on their ongoing activities can provide avenues for competitive differentiation.

The knowledge-based logic of organization provides a basis for understanding the microstructure that undergirds the capabilities of today's businesses. Although knowledge is held at all organizational levels, the most valuable knowledge remains unarticulated, taking the form of know-how, expertise, and individual intuition. Some knowledge is explicated and codified in the form of documents, procedures, and organizational routines. As knowledge at one level interacts with that at other ontological levels, new knowledge is created (Garud & Nayyar, 1994). As this new knowledge is used, some of it is formalized and codified in systems and technologies, while some becomes embedded in organizational routines.

Some of the earlier attempts to articulate the knowledge-based view have focused primarily on the knowledge creation process in organizations (e.g., Nonaka, 1994). Knowledge *creation* refers to the development of new knowledge through the interplay of tacit and explicit knowledge at different ontological levels (e.g. Nonaka & Nishiguchi, 2001). Most knowledge creation occurs within the context of social systems such as problem-solving groups and project teams. This phase of knowledge management has received a great deal of attention from management and organizational scholars.

Some new knowledge is explicated and formalized during the knowledge *codification* phase. Codification of tacit knowledge is facilitated by mechanisms that formalize and embed it in documents, software, and systems. At the simplest level, writing down the steps of a given process for executing a task represents knowledge codification. An example of such codified knowledge might be a service technician's troubleshooting manual for a photocopier.

A step-by-step recipe that a novice worker in a specialty coffee shop can use to make an Italian style "café latte" is another attempt at codification of tacit knowledge. The higher the tacit elements of the knowledge, the more difficult it is to codify. Codification of complex knowledge frequently relies on information technology. Expert systems, decision support systems, document management systems, and relational database tools represent some of the technological solutions developed primarily to support this phase of knowledge management. The codification phase has primarily received attention from both the information systems and the computer science research communities.

Knowledge *application* is the phase in which existing knowledge is brought to bear on the problem at hand. Knowledge creation and codification do not necessarily lead to improved performance, nor do they create value (Alavi, 2001). Value is created only when knowledge distributed throughout an organization is located and transferred from its previous site and applied where it is needed.

Consider the following example: A global oil company has invested millions of dollars in the development of a web-based knowledge repository. The repository contains the best practices, the most important lessons learned, and a host of principles, techniques and procedures which represent objectives of the firm's different divisions. The knowledge repository is hardly used and the firm's considerable investment in KMS goes unrealized (Watts Sussman, 1998). In this case, the firm is not realizing the full value of its knowledge assets.

On the other hand, one can point to organizations that have developed effective KMS strategies for knowledge integration and application leading to consistent product innovations and profitability. An exemplar in this category is the 3M company. In 1996, 3M produced over 400 new products. One of the goals of the CEO of the company was to generate 10 percent of the revenues from new products--that is, products that were less than one year old (Davenport and Prusak, 1997). Such a high level product innovation and profitability at 3M are achieved through rapid knowledge creation and effective knowledge application processes. The company highly values and promotes knowledge application and has invested considerable resources to develop technical and organizational infrastructures and processes for this purpose. For example, an on-line database of technical expertise is available throughout the firm; the company sponsors an annual three-day knowledge fair; and the researchers are given time not only to access technical knowledge but also to experiment, absorb, and apply the knowledge (Davenport and Prusak, 1997). These examples demonstrate that despite organizational desire and efforts to share and apply knowledge, its actual transfer and application do not occur easily and effortlessly.

Theoretically, both knowledge creation and knowledge codification phases have received the most scholarly attention. Knowledge application has received relatively little attention. Paradoxically, the phase contributes the most to value creation. In this paper, we turn our attention to this key phase of knowledge management.

Knowledge Application in Organizations

An important aspect of knowledge management is enhancing the organizational knowledge application process. Knowledge leads to organizational value when it is used to produce effective performance. Creation, codification, and storage of new knowledge without its exploitation (i.e., application) leads to its underutilization as a driver of performance (March, 1991; Alavi, 2001). Organizations that excel at knowledge application are inherently better at continuously translating their intellectual capital into innovative products and services.

The realization that knowledge application is the key predictor of value creation is not new. Penrose (1959) recognized this fact in her conceptualization of a resource as a bundle of possible services. Its value, she argued, hinges primarily on the services that an organization derives from it rather than on its ownership. Clearly, knowledge assets are of value only to the extent that they are actually applied in the operations of an organization. Since the most valuable of any organization's knowledge is tacit, its members' ability to pool and apply their tacit knowledge is the most pronounced predictor of its value.

Knowledge integration is a key facet of knowledge application. We define knowledge integration as the synthesis of individuals' specialized knowledge into situation-specific systemic knowledge. Knowledge exists in firms and networks only in a metaphorical sense. Knowledge, especially tacit knowledge such as expertise and know-how, is held only in the individuals' minds. Tacit knowledge is manifested only through action. The value of individual and organizational knowledge resides primarily in its application, an activity that we view as the crux of knowledge management. Collectives of individuals such as teams provide the context in which individuals' tacit knowledge can be pooled and recombined to create group-level knowledge (De Boer, Van den Bosch, & Volberda, 1999). This knowledge is the outcome of an integration process.

Grant (1996) describes the integration of individuals' specialized knowledge to create value as a key capability. Strategy theorists label it the cornerstone of dynamic capabilities (Eisenhardt & Martin, 2000), while innovation management scholars describe it as a meta-capability (e.g., Henderson & Cockburn, 1994). We believe that knowledge integration is a key component of knowledge application for three reasons. It premeditates the ability of organizations to (1) sense, (2) interpret, and (3) respond to new business opportunities and threats. These three activities are discussed below.

Organizations use triggers and stimuli to sense threats and opportunities (Arrow, 1974). As an organization is a social system of individuals, its systemic character arises from the ability of its constituents to interrelate to each other's actions. Without its systemic characteristics, it is likely to operate as an un-orchestrated collection of individuals. In such social systems, most individuals must specialize within a narrow domain if efficiencies are to be maintained. However, when changes in the business or technological environment occur, it is difficult for these individuals to sense these changes beyond what they can relate to through their preexisting knowledge bases. When distributed knowledge is effectively integrated, social collectives such as teams and organizations begin to function as a robust and well-coordinated system. Individual members of the organization then assume the role of multiple potential receptors, each helping peers to sense stimuli within the given domain of specialization (Hargadon & Sutton, 1997). Knowledge integration therefore increases the likelihood that organizations will reliably sense emerging threats and opportunities.

Individuals use perceptual filters to interpret new streams of information. Based on their interpretations, they can choose either to use this new information or disregard it as noise. In social collectives, preexisting requisite knowledge determines the collectives' ability to interpret new information (Cohen & Levinthal, 1990). Knowledge integration provides a larger shared base of comprehensible knowledge, effectively improving the ability of a social system to interpret diverse information stimuli collectively.

New opportunities and threats that have been both sensed and interpreted might call for rapid response. When the knowledge to effectuate a response exists but an organization cannot rapidly bring it to bear, an opportunity can easily be lost. When the requisite knowledge is not present, it must be created. Existing work on organizational learning and knowledge management has emphasized knowledge acquisition as a mechanism to access such knowledge. The inefficiencies and time demands of knowledge acquisition and transfer might lead to the inability of the organization to respond in a timely manner. This constraint is especially pronounced in "high clock-speed" industries—ones that are characterized by turbulent business models and rapidly evolving technologies (Mendelson & Pillai, 1998). Integration of existing and new knowledge is by definition a more efficient response mechanism, which does not lead to time constraints for creating new knowledge. Knowledge integration therefore underlies firms' abilities to recognize and rapidly respond to opportunities and threats.

Approaches to Knowledge Integration

Distributed knowledge can be applied either through transfer or through integration. Transfer-driven application is inherently time-consuming and inefficient. The uncertainty and speed with which existing knowledge must be pooled and the short half-life of innovative knowledge lower the attractiveness of transfer-driven knowledge application (Ciborra, 1996;

Darr, Argote, & Epple, 1995). Integration provides a faster and relatively inexpensive mechanism because it involves synergistic synthesis of disparate specialized knowledge without extensive communication or transfer of that knowledge

Integration can be effectuated in three ways: (1) directives, (2) routines, or (3) self-contained task-teams (Grant, 1996). Directives are defined as the specific sets of rules, procedures, heuristics, and instructions developed through the articulation of specialists' tacit knowledge for efficient application by non-specialists. Routines refer to organizational protocols, process specifications, and interaction norms through which individuals apply and integrate what they know without having to communicate it explicitly. Self-managing teams are the third and perhaps most important mechanism. Teams provide a viable mechanism for the integration of knowledge for complex and non-routine organizational tasks, especially when task uncertainty, novelty, and complexity preclude the use of existing routines or directives. Through a team structure, diverse knowledge and expertise of individuals at various locations in an organization can be assembled, integrated, and applied to the task at hand. Rich communication, collaboration, and creative conflict characterize knowledge integration in teams. Reconfiguration of distributed organizational knowledge using team structures facilitates innovation beyond that possible from using solely directives and routines. By encompassing diverse sources of specialized knowledge, teams enhance an organization's ability to innovate (Boutellier, Gassmann, Macho, and Roux, 1998; Madhavan and Grover, 1998). In this paper, therefore, we focus on task-oriented teams as a primary means of knowledge integration.

Facilitating Knowledge Integration in Virtual Team Environments

About half a century ago, Penrose (1955: 542) predicted the challenges in balancing coordination of knowledge and efficiency as organizations became increasingly distributed.

Virtual teams are an increasingly prevalent form of work structures in the 21st century (Handy, 1995; Sole and Applegate, 2000; Townsend, DeMarie, and Hendrickson, 1998). The prevalence and increase in virtual teamwork may be attributed primarily to the need for specialized knowledge and expertise, globalization, and employee preferences (Boutellier, Gassman, Macho, and Roux, 1998). Although the logic of virtual structures has provided organizations unprecedented ability to work across temporal and spatial boundaries (Boudreau, Loch, Robey, & Straub, 1998), it brings with it unfamiliar management challenges.

As mentioned earlier, the ultimate objective of any organizational knowledge management initiative ought to be knowledge application and exploitation and not just the creation and stock piling of content. However, existing literature on knowledge management systems does not seem adequate to address the considerable complexity and challenges of knowledge integration process in team settings. This process tends to be treated as a simple aggregation of team members' knowledge (Yoo and Kanawattanachai, 2001). Teams are distributed knowledge systems. Unlike individuals, they do not share a central physical mind and memory. A team's knowledge and cognition is socially shared among the individuals who constitute the team (Hutchins, 1995; Weick and Roberts, 1993). Thus, a prerequisite for effective knowledge integration in teams is knowing who has the required knowledge and expertise, where the knowledge and expertise are located, and where they are needed. Furthermore, effective teamwork (in both virtual and face-to-face settings) requires an emergent process of rich exchanges and joint problem-solving to integrate and apply knowledge and expertise to the task at hand in a coordinated manner. This process in turn requires an environment supportive of easy, frequent, content- and context-rich interpersonal interactions.

Studies in innovation management (e.g., Ahuja, 2000; Johnsson, 2000) and organizational learning (e.g., Hinsz, 1990; Walsh, 1995) have shown that diversity of knowledge and the distributed nature of cognition in team settings create challenges to knowledge integration in these settings. These challenges become more pronounced in virtual team environments. Virtual environments are defined as settings in which individuals work across space, time, and organizational boundaries to execute interdependent tasks with communication links primarily established and supported through information technologies (Maznevski & Chudoba, 2000).

In this section, through our review of communication and group literature, we identify four specific knowledge integration challenges in virtual team settings: (1) constraints on transactive memory, (2) insufficient mutual understanding, (3) failure in sharing and retaining contextual knowledge, and (4) inflexibility of organizational ties. We then propose ways in which KMS may be designed to meet these challenges effectively.

Constraints on Transactive Memory

Wegner and his colleagues (Wegner, 1986; Wegner, Guiliano, and Hertel, 1985) identified two types of memory: (1) internal memory, defined as knowledge held in an individual team member's mind, and (2) external memory, which consists of knowledge that is not held in the mind of a team member but which rather can be located and retrieved when the team member needs it. External memories as defined here may reside in other team members, or may be contained in storage devices such as documents and computer files or databases. External memories are accessed through directories held in the mind of individual team members that identify existence, location, and mechanisms for retrieval of knowledge held by other team members or in various storage devices. The development of directories and the encoding and retrieving of knowledge in teams are facilitated by rich and iterative communication interactions or transactions (hence the term *transactive* memory) (Anand et al., 1998). Directories also contain *labels* that team members attach to chunks or classes of knowledge for classification and retrieval purposes (Anand, et al. 1996). When team members use the identical labels to tag knowledge, they can relatively easily and efficiently access and share knowledge among themselves. Empirical studies have shown that effective transactive memory systems enhance team members' knowledge contributions and task performance in complex task environments (Faraj and Sproull, 2000; Lewis, 2000, Moreland, 1999; and Yoo and Kanawattanaich, 2001).

Thus, transactive memory enables individuals to pool their tacit knowledge in solving the collective task. It provides individuals the direction for searching for the complementary knowledge needed to complete a given team task. Individuals can use this memory to access and retrieve knowledge which is not personally known to them but which they recognize as existing elsewhere in the organization.

Transactive memory is developed over time and primarily through direct interactions with and observation of team members in action. Previous research on transactive memory has focused mostly on face-to-face interactions (Anand, Manz, & Glick, 1998). Physical distance between team members, indirect technology-mediated interactions between them, a lack of antecedent collaborative history, and the typical diversity in expertise and backgrounds of virtual team members constrains the development and maintenance of transactive memory in virtual settings. In these settings, in which development of transactive memory is constrained, team members cannot easily share their specialized knowledge or bring it to bear on the team task. As a result, the quality and/or efficiency of knowledge integration suffers, and individuals may expend considerable resources on attempting to acquire or to locate and retrieve the needed complementary knowledge. Thus, a major role for KMS in virtual team environments may be the development and support of transactive memory. Based on the preceding argument we propose that:

Proposition 1: KMS support of a virtual team's transactive memory enhances the team's knowledge integration process.

This may be accomplished through creation of on-line "yellow pages" containing profiles of team members, searchable libraries of codified knowledge relevant to team task, as well as electronic bulletin boards where team members can post questions and seek other team members' assistance and knowledge. Consider the following examples of a KMS for support of transactive memory.

The consulting firm of Ernest and Young supports the transactive memory of its consulting teams (both virtual and face-to-face consulting teams) through the development of online knowledge repositories (Hansen, Nohria, and Turney, 1999). The searchable repositories contain codified knowledge from a variety of internal and external sources including competitive intelligence and industry trends as well as internal reports and the firm's best practices. Consulting team members from remote locations access the knowledge repositories through the firm's intranet and locate and retrieve the required items by using search engines. Another management consulting firm uses computerized yellow pages or knowledge maps to form and support its virtual teams. Yellow pages are directories that capture and inventory the knowledge, experience, and backgrounds of the firm's consultants. These directories are used in assembling the virtual project teams to ensure that the required mix of knowledge and expertise is present in the team. The yellow pages also assist in the assignment of project tasks and the division of activities among various team members based on their domain expertise.

Insufficient Mutual Understanding

Mutual knowledge is the knowledge that actors in a virtual organization both share and know that they share (Cramton, 2001). It lies at the intersection of the specialized knowledge sets that a virtual organization must integrate. According to Clark and his colleagues, such "common ground" is a key ingredient of effective communication and collaboration in team settings (Clark 1996; Clark and Carlson 1982; Clark and Marshall 1991). Mutual understanding among team members enhances comprehension and interpretation of the information that is communicated among them (Krauss, 1992; Krause and Fussell, 1990). This understanding occurs because it enables the team members to formulate their contributions with an awareness of what other team members do and do not know (Krauss and Fussell, 1990) and because it uses aspects and "language" of the commonly held knowledge. Mutual understanding in team settings is developed through joint training and development (Liang et al., 1995; Moreland et al. 1996) and through firsthand experiences and joint problem-solving among team members (Krauss and Fussell, 1990). When mutual knowledge is incomplete, individuals' ability to interrelate to the group as a whole is lower (Van den Bosch, Volberda, & Boer, 1999). When group members are unable to interrelate to each other's expertise, knowledge integration is unlikely to occur effectively or efficiently.

It is easy to see how the circumstances of virtual teamwork (i.e., dispersion of team members in space and time, diversity of expertise and/or culture, and absence of a work history among the team members) constrain the development of shared understanding among the team members by raising barriers to effective communication among them. In the absence of shared work environments, common colleagues, and ongoing social interactions, members of virtual teams must establish mutual understanding through alternative means. For example, in the virtual team settings due the technology-mediated interactions, communication feedback between interacting team members is constrained due to delay or elimination of paraverbal or nonverbal cues. This can lead to delay in detection of communication errors or misinterpretations, which in turn may result in misunderstandings and conflict among virtual team members. These issues are likely to be even more pronounced if the virtual environment spans functional, cultural, national, and organizational boundaries. Based on the argument above, we propose that:

> **Proposition 2:** KMS support of the development of mutual understanding among members in virtual environments enhances the knowledge integration process.

The integration process may be accomplished through KMS features that facilitate rich, multi-channel and synchronous collaboration and timely feedback among team members. Other useful KMS features include tools for easy and rapid development of models or prototypes that can be viewed, manipulated, and modified in real-time by all the team members and can be saved for future use and reference. The proposed KMS approach is demonstrated through the following example, adapted from Malhotra, et al. (2001).

Boeing-Rocketdyne, a U.S. manufacturer of liquid fueled rocket engines, initiated an inter-organizational virtual team to design a new and highly efficient rocket engine. At the start of the project, no shared understanding or common grounds existed among the team members due to a lack of previous experience working together, to differences in professional expertise, and to the different organizational affiliations of the team members. In the absence of face-to-face meetings, a specially designed KMS provided a forum and a supportive environment for collaboration and for the development of the shared understanding required for successful completion of the project. The KMS consisted of communication and messaging capabilities and an electronic whiteboard, as well as an easy to search knowledge repository. All the team members were easily and securely able to access the KMS capabilities remotely. The entries in the knowledge repository could consist of sketches, snapshots, hotlinks to desktop applications, and documents or templates. Each team member was able to create, comment on, modify, search, or reference-link the entries in the repository. In order to develop a "common language" for the project team and to facilitate search and retrieval of the entries in the knowledge repository, a list of keywords was pre-specified by the team and used to describe and classify the entries. Furthermore, it was decided that when extensive changes to existing entries are needed, a new entry should be created and linked to the existing one in order to preserve and observe the evolution of thoughts and ideas. The electronic whiteboard allowed real-time access to and manipulation of the same entry. Furthermore, modeling tools enabled real-time illustration and analysis of ideas. Malhotra et al. (2001) provide an interesting example: during a teleconference, while all the team members were logged into the system, one of the engineers sketched an idea on the whiteboard. The idea involved drilling a certain number of holes into a metal plate. As the debate about the number and location of the holes continued, another engineer at a remote location used his desktop CAD (computer assisted design) tool to develop a more accurate and detailed drawing of the sketch. The analysis of the CAD drawing indicated that the metal plate was not large enough for all the required holes. The team then proceeded to modify the design in real-time and to develop a feasible solution.

Failure in Sharing and Retaining Contextual Knowledge

By definition, members of a virtual team are dispersed across multiple locations. Therefore, the work context of individual team members varies along several dimensions, including organizational climate and culture, physical layout, competing work demands, and access to information and technology. In co-located teams, contextual knowledge is typically shared and understood through direct observation and shared experience. In face-to-face environments, visiting team members' offices, attending the same meetings, working in the same locale, and experiencing the same or similar organizational culture and environment all contribute to shared understanding of the team's context. In virtual team settings, on the other hand, contextual knowledge seems to be held uniquely and tends to be unevenly distributed among team members. Studies of face-to-face teams have showed that they tend to share and discuss commonly held information and to overlook uniquely held information (Stasser and Stewart, 1992; Stasser and Titus, 1987). Uniquely held information, if mentioned, tends to be less salient to other team members, and therefore it fails to draw attention and to be retained (Cramton, 2001). Virtual environments neither possess the mechanisms to accurately communicate the context nor the storage mechanisms to facilitate later retrieval and use (Thomas, Watts-Sussman, & Henderson, 2001). Failure to share and remember contextual knowledge in virtual team environments may lead to misunderstandings or misinterpretation of a remote team member's behavior. For example, a delay in responding to a remote team member's e-mail due to an equipment failure, travel, or a local holiday may instead be attributed to disinterest, laziness, or disagreement. These forms of negative personal attributions in turn may lead to conflict and difficulty in coordination of team efforts, often with detrimental effects on team performance and outcome (Cramton, 2001; Nisbett et al., 1973). Unless enabling information technology can provide mechanisms for maintaining the context of discourse, messages of disproportionately higher complexity must be exchanged to coordinate even the simplest of actions (Maznevski & Chudoba, 2000). Based on this argument, we propose that:

Proposition 3. KMS support for sharing and retaining contextual knowledge in virtual environments enhances the knowledge integration process.

Consider the British Petroleum's Virtual Teamwork Program knowledge management system (Davenport and Prusak, 1997). The system consists of a set of integrated hardware and software tools, including desktop videoconferencing, groupware, multimedia e-mail, and shared whiteboards that enabled the ad hoc creation of rich communication networks among virtual team members to capture and convey the team members' context. In one instance, when the operations on a North Sea mobile drilling ship came to a halt due to equipment failure, the Virtual Teamwork Program KMS was used to diagnose and solve the problem quickly and efficiently. Through use of a satellite link, an ad hoc video and audio communication network was established between the engineers on the ship and drilling equipment engineers in Aberdeen in eastern Scotland. The engineers in Aberdeen, visually examining the broken equipment through the video link and synchronous interactions and carrying on discussion with the ship engineers (the remote members of the team), were able to diagnose the problem and lead the ship engineers through the necessary repairs in a few short hours. Diagnosing the problem and fixing the broken part without the Virtual Teamwork Program KMS, which enabled sharing of the context by viewing the situation on the ship and engaging in joint trial and error problem solving, would have required dispatching the experts to the ship and would have led to considerable delay and cost.

Inflexibility of Organizational Ties

When relatively independent organizational units initiate collaboration, the ties that bind them are weak (Hite & Hesterly, 2001). Ties among members of a team are considered weak when they are distant and their interactions are infrequent (Hansen, 1999). Weak ties are conducive to the discovery of new unshared knowledge and to the establishment of new knowledge combinatorial opportunities. However, knowledge sharing is facilitated by strong ties, which are costlier to maintain in the long run (Granovetter, 1973). Such ties are characterized by close and frequent personal interactions among team members. This clearly creates a dilemma for organizations. If managers incur the expense of maintaining strong ties to facilitate knowledge sharing, they also reduce the likelihood of innovation and developing novel knowledge.

In virtual environments, the burden of strengthening ties to facilitate knowledge integration and application falls squarely on the shoulders of the enabling information technology. If the ties enabled by IT are not strong enough (i.e., provide for rich, easy and frequent communication among the virtual team members), knowledge may be shared unevenly across the virtual environment. Uneven distribution will result in the failure of some members of the virtual group to receive knowledge that some of their peers possess. Such knowledge asymmetries in turn cause "glitches" (Hoopes and Postrel, 1999). KM systems can foster transitory strong ties within weakly coupled sub-networks of individuals by building trust and by facilitating reciprocity in transactions. Trust can be built within the context of temporary collaborations by maintaining a history of individual interactions and making feedback from past engagements accessible to future collaborators. Likewise, feedback mechanisms also provide a reliable source of an individual's history of reciprocating to information sharing.

Based on this argument, we propose that:

Proposition 4. KMS support for fostering strong ties in virtual environments enhances the knowledge integration process.

Consider Saatchi & Saatchi Worldwide, a global advertising agency that employs about 7,000 individuals across its offices in 95 countries. The global reach of the company has also made it difficult for its executives to coordinate advertising campaigns across its global clients (Gill, 2001). The most frequently used format used by the firm is videotape. Executives had long relied on shipping packages with videotaped copies of its advertising content across offices–-a process that typically took from three days to a week. In 1996, when a global client requested more consistency in its advertising messages across its international markets, the company developed an Intranet-based system, the Saatchi Brain. This system allows account executives from across the world to share digitized version of advertising campaigns, online chat, document sharing, search functionality, and electronic messaging. Instead of having to search on the Web and call on several colleagues in different countries in order to find related content, executives can now log on to the Brain and search across its repository of advertising content and campaigns irrespective of location. Once a match it found, the executive can immediately access all relevant content and initiate collaboration with a previously unconnected colleague in another country. The ability to convert weak organizational ties into spontaneous strong ties through interactivity, collaboration, and rich information exchange has allowed Saatchi and Saatchi to more efficiently integrate its distributed expertise.

Summary and Conclusions

Although virtual environments promise access to diverse, specialized knowledge, they are intrinsically nonconducive to the integration and application of that expertise. Of the three phases of knowledge management, the one where value is created is the application phase. Unfortunately, this is also the least theoretically attended phase of knowledge management in organizations. In this paper, we have identified four key constraints to knowledge integration and application in such settings. These constraints involve the incompleteness of transactive memory, insufficient mutual understanding, failure in sharing and remembering contextual knowledge, and the inflexibility of organizational ties. Although the necessary expertise might be present in a virtual team, these constraints can render them incapable of rapidly drawing on their distributed expertise to solve emergent problems.

In this paper, we propose four high-level KMS approaches to address these inherent knowledge integration constraints in virtual teams (See Table 1).

Table 1. Knowledge integration challenges of virtual teams and the proposed KMS Approaches

Knowledge Integration Challenges of Virtual Teams	*Proposed KMS Approaches*
Shortcomings of Transactive Memory	- Searchable repositories of codified knowledge - Computerized "yellow pages" of employees skills and experience
Insufficient mutual understanding among team members	- Rich, multiple communication channels and a shared space for real-time collaboration among team members - Capabilities for rapid development and joint modifications of models and prototypes
Failure to share and retain contextual knowledge	- Opportunities for frequent, rich communication to share uniquely held information - - Creation of notification profiles to disseminate "local" contextual knowledge to all team members - Persistent individual identities, peer feedback records and project involvements spanning all previous projects
Inflexibility of organizational ties	- Trust building mechanisms - Peer-to-peer collaboration tools - Temporally stable history of individual contributions - Feedback recording and access mechanisms

The foregoing propositions bring several promising avenues for further research to the fore. The extant literature on KMS has focused on developing theoretical explanations either of systems or of design of the systems themselves. The two streams of work have largely been disjointed, in effect, using little empirical guidance to build systems and rarely evaluating KMS implementations empirically.

Examining the relative effects of transactive memory, mutual understanding, contextual knowledge sharing and retention, and organizational ties in both collocated and virtual groups will provide insights into the extent of these problems in both, as well as in each environment taken separately. Moreover, we recognize that the distinction between collocated and virtual team environments is a continuum rather than a crisp dichotomy. For example, an experiment that compares virtual group performance with and without "yellow page" mechanisms for creating transactive memory can yield insights into the contribution of such systems to group performance. Similarly, experimental comparisons of a group with and without context sharing and retention KMS features can yield insights into how these KMS capabilities assist in knowledge integration. Understanding the issues raised here across both settings will guide further KMS design in hybrid environments (i.e., environments that involve both face-to-face and distributed technology-mediated interactions among the team members).

Comparing how context retention mechanisms affect knowledge integration and performance of inter- and intra-organizational virtual teams is another promising avenue for future work. It is possible that virtual teams that draw their members from within a single corporation boundaries experience fewer constraints on context communication and retention due to the members' shared affiliations and corporate identity. Since teams are often responsible for inter-organizational knowledge application, context management mechanisms might be more crucial to the performance of inter-organizational virtual teams.

Future research should also use a knowledge integration perspective to examine when and where team stability is preferred in virtual environments. Modular organizational ties among the team members will provide richer opportunities for multitudinous knowledge integration possibilities in project contexts that demand outcome novelty and innovation. Empirical work can provide insights into whether a virtual team that is kept intact across a family of related projects contributes to efficient knowledge integration or simply discourages innovation.

Future research should examine the influence of technological and business turbulence on the proposed relationships. For example, an experiment that compares the effect of transactive memory on knowledge integration in projects with rapidly changing requirements (business turbulence) or technology (technological turbulence) will provide insights into the mediating effects of turbulence on the transactive memory-knowledge integration relationship.

From a KMS design perspective; developers must break free from the assumptions that guide design of KMS for collocated and relatively stable teams. Since much work in organizations is now performed by small and temporary groups of individuals, often across the traditional hierarchies and organizational boundaries, the assumption of discontinuity must be explicitly modeled into KMS design. Trust, reciprocity, and peer perceptions guide individual behavior in knowledge-intensive virtual teams. IT-based mechanisms that allow individual identities to be maintained consistently across project groups and temporary assignments will facilitate better context formation and better expertise recognition.

We believe that excessive managerial emphasis on knowledge creation and codification implicitly focuses on the present and the past. The value of knowledge management lies in nurturing the ability to sense proactively and respond rapidly to emerging events. To build such forward-looking KMS, managers must facilitate knowledge integration and application through theoretically guided KMS designs. Thoughtfully designed KMS can decouple process knowledge from the short-term requirements of individual teams. They can facilitate novel reconfigurations of resources and knowledge in purposively opportunistic ways. In the long run, organizations cannot be differentiated by how much they know but by how well they use what they know.

References

Ahuja, G. (2000). Collaboration Networks, Structural Holes, and Innovation: A Longitudnal Study. *Administrative Science Quarterly, 45*, 425-455.

Alavi, M. (2000). Managing Organizational Knowledge. In *Framing the Domains of IT Management. R.W. Zmud (Ed). Cincinnati, Ohio: Pinnaflex Educational Resources, Inc.*

Alavi, M. (2001). Knowledge Management and Knowledge Management Systems: Conceptual Foundations and Research Issues. *MIS Quarterly, 25*(1), 107-136.

Anand, V., Manz, C., & Glick, W. (1998). An Organizational Memory Approach to Information Management. *Academy of Management Review, 23*(4), 796-809.

Arrow, K. (1974). *The Limits of Organization*. New York: Norton.

Boudreau, M.-C., Loch, K. D., Robey, D., & Straub, D. (1998, Nov). Going Global: Using Information Technology to Advance the Competitiveness of the Virtual Transnational Organization. *The Academy of Management Executive, 12,* 120-128.

Boutellier, R. Gassmann, O. Macho F. & Roux M. (1998). Management of Dispersed Product Development Teams: The Role of Information Technologies. *R&D Management,* 28, 1, 13-26.

Ciborra, C. (1996). The Platform Organization: Recombining Strategies, Structures, and Surprises. *Organization Science, 7*(2), 103-118.

Clark, H. (1996) *Using Language.* New Yourk: Cambridge University Press.

Clark, H. & Carlson T. (1982). Speech Acts and Hearer's Beliefs. In N. Smith (Ed.). *Mutual Knowledge.* New York: Academic Press. 1-36.

Clark, H. Marshall C. (1981). Definite References and Mutual Knowledge. In A. Joshi, I. Sag, & B. Webber (Eds.) *Elements of Discourse Understanding*, New York: Cambridge University Press, 10-63.

Cohen, W., & Levinthal, D. (1990). Absorptive Capacity: A New Perspective on Learning and Innovation. *Administrative Science Quarterly, 35*, 128-152.

Cramton, C. (2001). The Mutual Knowledge Problem and Its Consequences for Dispersed Collaboration. *Organization Science, 12*(3), 346-371.

Darr, E., Argote, L., & Epple, D. (1995). The Acquisition, Transfer, and Depreciation of Knowledge in Service Organizations: Productivity in Franchises. *Management Science, 41*(11), 1750-1762.

Davenport, T. H. & Prusak, L. (1997). *Working Knowledge.* MA: Harvard Business School Press.

De Boer, M., Van den Bosch, F., & Volberda, H. (1999). Managing Organizational Knowledge Integration in the Emerging Multimedia Complex. *Journal of Management Studies, 36*(3), 379-418.

Eisenhardt, K., & Martin, J. (2000). Dynamic Capabilities: What Are They? *Strategic Management Journal, 21*, 1105-1121.

Faraj, S. & Sproull L. (2000). Coordinating Expertise in Software Development Teams. *Management Science*, 46,12, 1554-1568.

Gill, P. (2000). Going to the Videotape, *Knowledge Management*. 18-19.

Garud, R., & Nayyar, P. (1994). Transformative Capacity: Continual Structuring by Intertemporal Technology Transfer. *Strategic Management Journal, 15*, 365-385.

Granovetter, M. (1973). The Strength of Weak Ties. *American Journal of Sociology, 78*, 1360-1380.

Grant, R. (1996). Prospering in Dynamically-competitive Envoirnments: Organizational Capability as Knowledge Integration. *Organization Science, 7*(4), 375-387.

Handy, C. (1995). Trust and the Virtual Organization. *Harvard Business Review.*73,3, 40-49.

Hansen, M. (1999). The Search-Transfer Problem: The Role of Weak Ties in Sharing Knowledge Across Organizational Subunits. *Administrative Science Quarterly, 44*, 83-111.

Hargadon, A., & Sutton, R. (1997). Technology Brokering and Innovation in a Product Development Firm. *Administrative Science Quarterly, 42*, 716-749.

Henderson, R., & Cockburn, I. (1994). Measuring Competence? Exploring Firm Effects in Pharmaceutical Research. *Strategic Management Journal, 15*(Winter Special Issue), 63-84.

Hinsz, V. (1990). Cognitive and Consensus Processes In Group Recognition Memory Performance. *Journal of Personality and Social Psychology, 59*, 705-718.

Hite, J., & Hesterly, W. (2001). The Evolution of Firm Networks: From Emergence to Early Growth of the Firm. *Strategic Management Journal, 22*, 275-286.

Hoopes, D., & Postrel, S. (1999). Shared Knowledge, "Glitches," and Product Development Performance. *Strategic Management Journal, 20*, 837-865.

Huchin, E. (1995). *Cognition in the Wild.* Boston, MA: MIT Press.

Johnsson, S. (2000). Innovation in the Networked Firm: The Need to Develop New Types of Interface Competence. In J. Birkinshaw & P. Hagstrom (Eds.), *The Flexible Firm: Capability Management in Networked Organizations* (pp. 106-127). Oxford: Oxford University Press.

Krauss, R. & Bricker P. (1990). Effects of Transmission Delay and Access Delay on the Efficiency of Verbal Communication. *Journal of Acoustical Society,* 41, 286-292.

Krauss, R. & Fussell S. (1990). Mutual Knowledge and Communicative Effectiveness. J. Galagher, R. Kraut & C. Egdio (Eds.). *Intellectual Teamwork: Social and Technological Foundations of Coorperative Work.* Hillsdale, NJ: Lawrence Erlbaum. 111-146.

Madhaven, R. & Grover, R. (1998). From Embedded Knowledge to Embodied Knowledge: New Product Development as Knowledge Management, *Journal of Marketing* 62, 4, 1-12.

Msalhoutra, A. Majchrzak, A. Carmen, R. & Lott, V. (2001). Radical Innovation Without Collocation: A Case Study at Boeing-Rocketdyne. *MIS Quarterly.*25, 2, 229-249.

Maznevski, M., & Chudoba, K. (2000). Bridging Space Over Time: Global Virtual Team Dynamnics and Effectivness. *Organization Science, 11*(5), 473-492.

Mendelson, H., & Pillai, R. (1998). Clockspeed and Informational Response: Evidence from the Information Technology Industry. *Information Systems Research, 9*(4), 415-432.

Moreland, R.L. (1999). Transactive Memory: Learning Who Knowledge What in Work Groups and Organizations. L.L Thompson, J.M. Levine & D.M. Meseick (Eds.), *Shared Cognition in Organizations*, 3-31. Hillsdale, N.J.: Lawrence Erlbaum Associates.

Nonaka, I. (1994). A Dynamic Theory of Organizational Knowledge Creation. *Organization Science, 5*, 14-37.

Nonaka, I., & Nishiguchi, T. (2001). Social, Technical, and Evolutionary Dimensions of Knowledge Creation. In I. Nonaka & T. Nishiguchi (Eds.), *Knowledge Emergence: Social, Technical, and Evolutionary Dimensions of Knowledge Creation* (pp. 286-289). New York: Oxford University Press.

Penrose, E. (1955). Limits to the Growth and Size of Firms. *American Economic Review, 45*(2), 531-543.

Penrose, E. (1959). *The Theory of the Growth of the Firm*. Oxford: Basil Blackwell.

Schumpeter, J. (1939). *Business Cycles: A Theoretical, Historical, and Statistical Analysis of the Capitalist Process*. New York: McGraw Hill Book Company, Inc.

Sole, D. &Applegate L. (1999). Knowledge Sharing Practices and Technology Use Norm in Dispersed Development Teams. Working Paper, Harvard Business School, Boston, MA.

Thomas, J., Watts-Sussman, S., & Henderson, J. C. (2001). Understanding Strategic Learning: Linking Organizational Learning, Knowledge Management, and Sensemaking. *Organization Science, 12*(3), 331-345.

Townsend, A.M. De Marie, S.M. & Hendrickson, A.R. (1998). Virtual Teams: Technology and the Workplace of the Future. *Academy of Management Executive*, 12,3, 17-29.

Tsoukas, H. (1996). The Firm as a Distributed Knowledge System: A Constructionist Approach. *Strategic Management Journal, 17*(Winter Special Issue), 11-25.

Van den Bosch, F., Volberda, H., & Boer, M. (1999). Co-evolution of Firm Absorptive Capacity and Knowledge Environment: Organizational Forms and Combinative Capabilities. *Organization Science, 10*(5), 551-568.

Walsh, J. (1995). Managerial and Organizational Cognition: Notes from a Trip Down Memory Lane. *Organization Science, 6*(3), 280-321.

Watta-Sussman, S. (1998). *Adoption of Mediated Knowledge in Organizations: Source Credibility and Inforamtion Usefulness.* Unpublished Doctoral Dissertation, Boston University. Ann Arbor, Michigan: UMI Dissertation Services, Bell and Howell.

Weick, K. E. & Roberts, K.H. (1993). Collective Mind in Organizations: Heedful Interrelating on Flight Decks. *Administrative Science Quarterly,* 38, 357-381.

Wegner, D.M. (1986). Transactive memory: A Contemporary Analysis of the Group Mind. In B. Mullen & G.R. Goethals (Eds.). *Theories of Group Behavior* . 185- 208. New York: Springer-Verlag.

Wegner, D.M. Guiliano, T. & Hertel, P. (1985). Cognitive Interdependent in Close Relationships. In W.J. Ickes (Ed). Compatible and Incompatible Relationships 253-276. New York: Spring-Verlag.

Yoo, Y. & Kanawattanachai, P. (2001). Development of Transactive Memory and Collective Mind in Virtual Teams, Paper presented at the Annual Meeting of the Academy of Management, Washington, D.C.