KNOWLEDGE MANAGEMENT IN VIRTUAL PROJECTS:

A RESEARCH AGENDA

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Abstract

Project teams within organizations have many challenges to overcome in doing their work. As computer and collaboration technologies allow project team members to be increasingly dispersed in time, place, and organizational affiliation, even greater opportunities and challenges arise. This paper explores the issues associated with knowledge management in virtual project teams. The advantage of virtual projects is their flexibility to bring together members from diverse contexts for short-term endeavors. Knowledge, in contrast, is by nature a long-term phenomenon and emerges in stable social and organizational contexts. The paper describes some of the main challenges of bridging these contrasting requirements, especially the transferability of knowledge to and from the project. A typology of projects is presented, along with a framework that focuses on the management of virtual projects in particular. Research questions in the management of virtual projects are presented, and an integrated approach for examining those questions is discussed.

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Introduction

Projects are arguably one of the most common ways of managing organizational efforts. Projects are the prevalent organizational form of knowledge-intensive efforts, e.g., research and development, innovation, consulting, or organizational change efforts. A project may be defined as at least one person becoming involved in the planning and/or execution of a task. When several people are involved in a project—or in several projects—more complex situations entail. Complexity increases even more with such factors as geographical dispersion, different organizational affiliation, and cross-cultural efforts. So-called virtual projects are becoming more common, partly due to the globalization of the economy and accompanying business requirements, but also because scarce resources force knowledge, equipment, and capital to be shared.

Clearly the advent of new technological capabilities has made it possible for virtual teams to work on virtual projects in ways that were previously unimaginable. Great gains have been made, but there are still many difficulties that keep virtual teams from performing as effectively as a traditional, face-to-face team (Jarvenpaa & Ives; 1994; Lipnack & Stamps, 1997). For instance, task coordination and communication difficulties can keep teams from sharing and managing the knowledge that is so critical to effective project performance. There are still many unanswered questions about the design and role of technology for enhancing knowledge management, and hence performance, of virtual project teams.

In this paper, we approach virtual projects from the perspective of knowledge management. Our purpose is to define a way to examine how knowledge management within virtual project teams can be enhanced. We begin with a discussion of the difficulties of managing virtual projects, followed by a brief review of relevant literature. A typology of project types is presented, along with a framework that focuses on the management of virtual projects. Research questions in the management of virtual projects are presented, and an integrated approach for examining those questions is discussed.

Project Management and Knowledge Management

Coordination is a fundamental component of projects; team members need to know exactly when, what and how something is being done by which different stakeholders or resources. In the case of virtual projects, one may also need to know "where" such a task is being performed (Hamilton & Singh, 1992; Powell, 1993; van Krogh & Roos, 1992). "Where" may refer to a geographical location or to the relevant organizational context in which the project is executed (Ghoshal & Bartlett, 1994; Schein, 1984).

The coordination component of projects can be examined in knowledge management terms. Knowledge is often defined as meaningful information that is put into a particular context (Tuomi, 1999). Davenport and Prusak's (1998, p. 5) definition emphasizes the rich nature of knowledge: "Knowledge is a fluid mix of framed experience, values, contextual information, and expert insight that provides a framework for evaluating and incorporating new experiences and information." Knowledge management can be defined as the process of acquiring, creating, sharing, and using knowledge.

This view of knowledge management as a fundamental cornerstone of project management seems obvious. However, several differences create a disconnect between project management and knowledge management. First, projects are by nature finite endeavors, whereas knowledge is a commodity that should stay around as long as it is usable, typically far beyond the life of a single project. Second, project management is goal oriented and happens in spite of potential differences in culture, whether it be at the level of project teams, organizations, or even national entities. Projects also create their own distinct team and organizational context. Knowledge management, on the other hand, is not necessarily an end in itself. Knowledge is generated as project activities occur, and the socio-cultural context that generated that knowledge is a key component of it. In short, projects create the necessity to manage knowledge across time and in a multi-context setting.

Given these differences, a critical issue is how to generate knowledge for a given project in a way that makes it available not only to other projects (i.e., across-project transferability) but also to future projects (across-time transferability). A related problem is the fact that most project managers do not explicitly budget for time to perform knowledge transfer. How, then, can we provide for effective knowledge management in such situations, and particularly for virtual projects?

Grant’s (1996) knowledge-based theory of the firm is a useful metaphor for addressing the synergies between virtual project management and the growing literature of knowledge management. According to Grant, knowledge creation lies with the individual, and the main role of the firm is knowledge application or integration. Knowledge can create value for the firm via the key characteristics of transferability, capacity for aggregation, appropriability, specialization, and requirements of production. The first two of these are particularly relevant to virtual project management.

Transferability is critical because it addresses to a large extent the exchange of explicit information regarding when, what, and how something is being done, and by which different stakeholders. Transferability is relevant both across projects and across time. Transferability can be either of implicit (to know how) or explicit (to know about facts and theories) knowledge (Kogut & Zander, 1992). However, the transferability of these two types of knowledge can vary considerably. Explicit knowledge transferability can be judged by an analysis of communication patterns, whereas implicit knowledge transferability needs to be judged by how the knowledge is applied. Nonaka and Takeuichi (1995) propose that knowledge can result from combination, or the conversion from one type of explicit to a different type of explicit knowledge. Combination is the process of systemizing concepts into a knowledge system, potentially combining different bodies of explicit knowledge. Some of the tacit knowledge used by good project managers could also be tremendously relevant if shared with other stakeholders. Nonaka and Takeuichi (1995) discuss the conversion of knowledge from tacit into explicit and vice-versa. Tacit knowledge is not easily visible and expressible, and many times may come from experience or learning through mistakes.

The conversion of tacit to explicit knowledge is called externalization, and is triggered by dialogue or collective reflection (Nonaka & Takeuichi, 1995). Techniques that help externalize knowledge include the existence of an appropriate organizational climate. Externalization holds the key to new knowledge creation because it creates new explicit concepts from tacit knowledge. Nonaka and Takeuichi suggest that the most efficient way to accomplish this process is a sequential use of metaphor, analogy and models. Metaphors are “the cognitive lenses we use to make sense of all situations. Intimately interconnected with the way we think, metaphors are fundamental in shaping reality” (Kendall & Kendall, 1993). Metaphors also create a “novel interpretation of experience by asking the listener to see things in terms of something else” and “create new ways of experiencing reality” (Donnellon, et al., 1986, p. 48 and 52). Nonaka and Takeuichi suggest that analogies can then be used to iron out the contradictions in metaphors. Finally, the resulting explicit concepts can be modeled.

The other value-creating characteristic of knowledge that is important for virtual project management is its capacity for aggregation, i.e., how feasible and convenient it is to connect and build upon different pieces of knowledge to develop further knowledge. Aggregation of knowledge depends to a large extent on the format in which it is presented to its potential user. Knowledge has to be presented in ways that its relevance to the task at hand becomes obvious, or with “handles” or identifiers that make connections across different ideas simpler and more efficient.

A Framework for Studying Virtual Project Management

In the previous section, we discussed the importance of knowledge management in project teams. The relevance of the transferability of knowledge across time and projects was discussed, and metaphors were suggested as a way to improve transferability of knowledge. We also suggested that the ability to aggregate knowledge was a valuable characteristic as well. Now we address the issue of whether there will be different needs for knowledge management across different types of projects. There are several ways to categorize projects, including within and across organizations. Evaristo and Fenema (1999) proposed a typology of projects that focused within organizations and was based on two dimensions: the number of locations (single versus multiple) and the number of projects (single versus multiple). The traditional project is a single project in a single location. Complexity increases when there are multiple projects in a single location (a co-located program), and in moving to a distributed project (single project in multiple locations). The most complex situation is the case of multiple projects in multiple locations. Complexity is due to many factors but in particular to managing multiple interdependencies across time, space, and projects. Although this framework highlights potentially important differences in knowledge management needs across location and number of projects, it does not emphasize the importance of key factors involved when projects cross organizational lines.

We propose an extension of the Evaristo and Fenema typology that categorizes projects regardless of the organization, thus adding the new concept of *affiliation dispersion*. Since our interest is in cross-organization projects rather than multiple projects within an organization, we focus this discussion only on the two dimensions of

(1) the degree to which team members are geographically dispersed, and (2) the degree to which the organizational affiliation of team members is dispersed. The first dimension is the familiar idea of place. The second dimension is unique in that it describes the extent to which project members have the same or different affiliations, whether to an organization, a culture, or a nation. Figure 1 shows the typology of project teams based on these dimensions. Both dimensions are defined in terms of "low" and "high" to recognize the complexity of the dispersion concept, e.g., geographic dispersion might be defined in terms of building, region, country, etc. rather than just single or multiple locations.

Geographic Dispersion of Team Members

		Low	*High*
Affiliation Dispersion of Team Members	*Low*	Traditional	Distributed
	High	Inter-organizational	Virtual

Figure 1. Typology of Projects Across Organizations

We propose that this extension provides interesting insights into differences in the effects of such factors as organizational culture, communication patterns, and skill sets, to name a few. Different factors are likely to be more or less important in different cells of the typology, and complexity increases as we move from the upper left cell (Traditional) to the lower right cell (Virtual). Opportunities for technology support also increase. As organizations develop sophistication and infrastructure for increasingly more complex project management, they move from traditional, to distributed, to interorganizational, and finally to virtual projects. The dimension of number of projects that is part of the original Evaristo and Fenema typology is another factor for consideration that is beyond the scope of this discussion.

The literature of project management generally addresses the *traditional* type of project, performed in a single location with a relatively homogeneous team, at least to the extent that project team members are all affiliated with the same organization and often in closely related departments. The problems addressed in traditional projects focus on such issues as resource assignment, task sequencing, coordination mechanisms, and management styles (e.g. Deephouse, et al., 1995-96; Shenhar, 1998; Ven der Merwe, 1997).

Increases in the sophistication of communication technology, coupled with increasing geographical dispersion of the organization's workforce, provide the impetus to move from traditional to *distributed* projects. Needs for both technology and human coordination rise rapidly. However, even though project members are distributed across multiple sites, they are still part of the same organization and hence somewhat homogeneous. Issues that are salient in this cell of the typology include such problems as communicating distributed information, effects on traditional structural boundaries, and changed coordination or work practices (Cramton, 1997; Hinds & Kiesler, 1995; Qureshi & Vogel, 1999).

The next shift is to *interorganizational* projects. These projects involve people who are relatively contiguous geographically but from a wide variety of organizational affiliations and most likely including independent consultants. Examples include task forces in local government or other public domains and alliances of local experts for specific one-time projects. Basic issues are the same as for traditional projects, but complexity is added by the introduction of social factors, cultural factors, and differing organizational environments. Although there are relatively few instances of this type of project in the literature, critical factors include complementarity of competencies and the ownership of results from the project (Teece, 1986).

The most complex and, for our purposes, most interesting type of project is the *virtual* project. Project team members are both widely dispersed geographically and in their organizational affiliation. All the issues mentioned in other types of projects apply here, with the interaction of these factors increasing the challenge of virtual project management. Of compelling interest is the appropriate technology infrastructure that will make virtual project management effective.

Any of the above scenarios could be made more complex by imagining the situation where some of the resources being used in an increasingly complex project (from traditional to distributed to interorganizational to virtual) also need to be shared across different projects. This would be the result of the combination of both typologies.

Based on both typologies above and our previous discussion, Figure 2 shows a framework for the study of virtual projects. We define four categories of input variables: (1) the external environment, (2) project characteristics(3) team member characteristics, and (4) technological environment. The general categories are consistent with other frameworks for the study of computer-mediated teams (e.g., Nunamaker, et al., 1991). The combination of input variables in these categories defines the human potential and technical infrastructure for communication and coordination. The knowledge management process is an on-going process by which team members use technology to achieve goals, which are the ultimate project outcomes that are relevant for a particular project. Feedback loops in the diagram reflect the idea that outcomes provide learning for future projects, and the knowledge management process may change how projects are defined, what members continue to be included, or the technology that is used. The concepts included in each component of the model are not exhaustive, but represent what is of most interest and relevance from a knowledge management perspective.

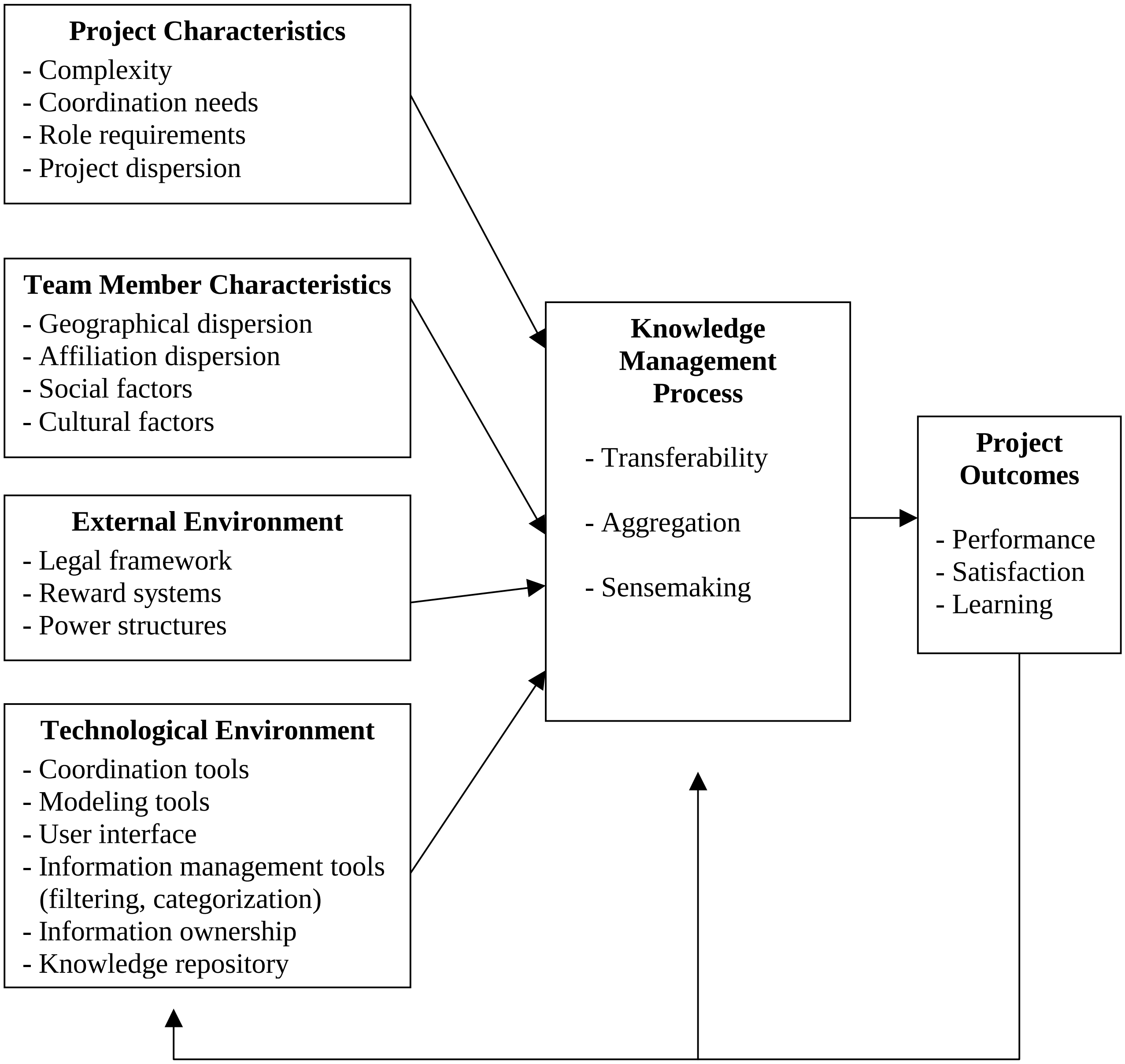

Figure 2. Framework for Research in Virtual Project Management

Agenda for Research

Virtual project management is a topic on which there is a dearth of literature. The research questions presented below are derived from the framework in Figure 2 and from more than twenty hours of interviews, brainstorming, and brain-writing undertaken with practicing managers in industry by the first author. Thus, the issues raised have both theoretical and practical significance, and reflect a useful starting point for research. The specific variables in each category of the framework are not exhaustive, but reflect factors that are most likely to be relevant to the knowledge management process in a virtual project environment. Questions are raised according to the major parts of the framework.

Project, Team, and External Environment

The first three categories of input variables are project characteristics, team member characteristics, and external environment. The project characteristics issues include for instance the difficulty of coordinating tasks in virtual project management. Although task coordination in traditional projects has been studied and modeled with such tools as PERT charts, little is known about coordination for virtual projects. What are best practices in coordinating virtual project tasks? What is the role of supervision in the quality of coordination? How does trust play a role in coordinating tasks across a virtual project (Cramton & Webber, 1999; Jarvenpaa, et al., 1998)? What specific characteristics of the technological environment contribute to coordination?

The second category of input variables is team member characteristics. Relevant issues include the impact that geographic and affiliation dispersion of the team members have on role requirements for managing virtual projects. Are new roles required, and how are roles shared among virtual team members? How relevant is the fact that different members might be originating from different cultures?

External environment variables are also relevant. For instance, regulatory issues may require that certain pieces of information should not cross borders, therefore artificially forcing a team structure other than the ideal one for the organization. Reward systems may emphasize individual performance differently than team behavior. Power structure within the organization may stem from expert power or position power, and these could affect how project knowledge is generated and shared. These are only a few examples of external issues that function as input variables to a knowledge management process.

Technological Environment

Since technology is of central interest here, we treat this category of input variables in more detail. A classic question regards the appearance of the user interface in order to achieve the best possible transferability of knowledge between the social and organizational subsystem and the information subsystem of the virtual project. How can the interface be made more user-friendly? How can it display the appropriate information in a way that maximizes use and coordination quality? In a related vein, how should training be conducted to use this system?

A particularly relevant question for technological environments in virtual projects is where ownership of the information should rest (Teece, 1988). This is critical given the variety of places where work is being performed on a given project. There are both advantages and problems to localization of ownership of knowledge and all its requisite parts. Decisions on information ownership are likely to affect organizational communication patterns and structure as well. How can we ensure such changes are taken into account and simplified to the extent possible?

These questions are design issues for the knowledge repository, which is of critical importance as the place where organizational memory about the project is created. The repository is not an information control mechanism, but a value-creating one (Jarvenpaa & Ives, 1994). The challenge is to capture, store, and present a wide variety of information in an easily accessible way. A number of researchers have started to address various parts of the problem, e.g., the Annotate system for distributed document collections (Ginsburg & Kambil, 1999). But the issues discussed earlier must be examined before a real knowledge repository can be implemented.

Knowledge Management Process

Earlier, we noted the importance of transferability and capacity of aggregation of knowledge in creating value for the firm (Grant, 1996). Therefore, a relevant question is how to increase the likelihood that a higher quantity and quality of knowledge will be transferred or aggregated. What characteristics of the technological environment increase knowledge transfer and aggregation?

One of the concepts presented earlier was the importance of metaphors in making knowledge explicit and hence being able to transfer it. This raises the obvious problem of better ways to create and agree on metaphors for the virtual team engaged in a virtual project. It also makes sense to explore the importance of the social context in evaluating these metaphors. All this is part of the concept of sensemaking.

Project Outcomes

The research questions presented are illustrative rather than exhaustive. Clearly, the ultimate objective is to examine the relationships among the different factors and how their interaction can improve performance on virtual projects. In most such cases, measurement of outcomes is an issue, and we expect that new metrics will have to be developed for assessing the quality of performance of virtual teams, particularly for the learning outcome.

Infrastructure and Method for Research

Virtual project management is still new, and as just discussed, ripe for many interesting research questions. Because of its relative newness, some of the methodological approaches to researching this topic are necessarily exploratory. Epistemologically, we follow Simon (1981) and perceive virtual project management as an artifact, of which the design in large part can most rapidly be understood from the combination of small tested findings. A systematic set of experiments will be conducted to clarify some of the critical issues raised earlier, with further focus on areas most likely to yield significant results. It is our intention to move as soon as possible to the analysis of realistic field situations, guided by the experimental results and following commitment from organizations to install the infrastructure to be developed. The next section describes the infrastructure for implementing the tools needed to engage in research in this area.

Infrastructure

The technological infrastructure will be a virtual engineering laboratory (VEL). The first instance of it will be built at the Center for Technology and Innovation Management at the University of BW-Munich.[1] Replications will be installed in other universities and organizations worldwide. At this point, we have interest from Federal University of Rio de Janeiro, Brazil; University College Dublin, Ireland; and University of Colorado, Boulder (USA). Organizations that have shown interest in participating in this study include large European auto manufacturers as well as large German high tech manufacturers.

The initial installation will include several rooms to simulate the distributed nature of a virtual project environment. The simulation will be used to iron out the details and logistics of a real, live system. The 100 Mbaud in-house network relieves the bandwidth constraints that still exist in today's wide-area-network traffic. Given the evolution of network technology, we expect these constraints to vanish in the five years to come. The objective, of course, is to eventually spread the software to the other locations listed above.

The hardware itself is by design fairly simple and relatively inexpensive. Each room will be equipped with a projection device, a pressure-sensitive whiteboard that can record hand prints or movements to share drawings, and connection to several laptops via LAN which will also enable various group support software tools. A video camera and microphones will be also available, both at the main workstation and in the other laptops

[1] About 200,000 US$ has already been secured to buy the necessary hardware and develop the appropriate software for the Munich installation.

(as many as there are team members in the room). At least in the first installation in Munich, a separate room that will allow a "project manager" to oversee the operations in the other three rooms will also be built. One of the capabilities included in this room, very much like videoconferencing managers, is to control and support the communications happening across the meeting rooms. Some of these characteristics have been defined in virtual meeting places such as the MIRROR project (Chappell, et al., 1992), though the emphasis has been more on electronic meetings than knowledge management *per se*.

Method and Vision for the System

The real challenge will be to develop and implement software that not only enables the coordination of virtual projects but also helps knowledge management within the organization. What follows is an initial vision of how this system would work based on the dynamics of the organizational context of the project. We envision people getting together virtually at the beginning of the project to create and define their tasks. Building on findings from group dynamics, this naturally created "storming" in the group can be considerably helped by the development of a tool that allows people to develop their own metaphor for the project they are joining. We take the motivation for the approach from observing frequent industrial applications, where we saw photos from social events or other idiosyncratic metaphors being used. For instance, in one case, a boat was used to describe the project, with its sail being the mission, the rudder its strategy, and so forth. Such a tool could be a combination of several group support systems (GSS) features with a common screen drawing feature. Discussion of the meaning of the "emerging" drawing or image would be through the GSS and communication features of the system. To support the communication component, tools will be implemented to allow asynchronous meetings (e-mail support, distribution lists, newsgroups using threading) but at the same time including agenda setting, calendaring, and other typical GSS tools such as brainstorming, voting, alternative evaluation (DeSanctis & Gallupe, 1987). To the extent possible, existing groupware tools will be integrated and/or extended within the VEL. For instance, experience with Lotus Notes shows that it has potential for knowledge management (Orlikowski, 1993; Schwabe, 1999). Prototypes of web-based GSS also exist (Dennis, et al., 1998; Romano, et al., 1998; Warkentin, et al., 1997). The challenge is to provide an integrated environment within a project management context.

The idea of developing project metaphors is similar to what Weick and Meader (1993) call sensemaking, which is particularly important in equivocal contexts such as virtual projects. Sensemaking is about meanings instead of problems. In their own words, "[it] involves efforts to construct moderately consensual definitions that cohere long enough for people to be able to infer some idea of what they have, what they want… [it] is about negotiation and construction of a mutually shared agreement of what causal linkages and outcome preferences constitute a confusing event" (p. 232). They go on to suggest that sensemaking can be helped by the activities of action, triangulation, affiliation, deliberation and contextualization. Our system will have an implementation inspired by these ideas, e.g., capability for teams to construct cognitive maps (Sheetz, et al., 1994) or use soft systems techniques such as rich picture diagrams (Checkland & Scholes, 1990) as a group. This idea is also consistent with Orlikowski (1993), who suggests that mental models, as embodied in metaphors used by the group, affect how people understand and appropriate meanings for groupware.

During the next few phases of group process (norming, performing), the group members would be using not only features from the group support system but also the tools that allow the group to communicate using graphical devices more easily. We believe that these graphical help features will make the use of metaphors easier during the entire process, thus enabling the knowledge management process.

Another important feature of the Virtual Engineering Environment will be the ability to provide for horizontal communication. Galbraith (1973) suggested that communication flows were very common vertically, with subordinates being able to get in touch with supervisors and vice versa. On the other hand, there were very few flows across people of the same hierarchical levels but in different functional departments. In this case, since members of the virtual team may be part of totally different functional areas, there is already increased communication by organizational design. Moreover, the types of e-mail filtering, summarizing and categorizing tools implemented within the software will allow people to send more information outside of the virtual team to the organization without being concerned with the generation of information overload. For instance, an e-mail may be addressed to “everybody” but subject to a certain filtering mechanism, such as profiles containing keywords. This could be a powerful way to manage existing knowledge.

The next step is to provide context-sensitive knowledge repositories that keep all information about project tasks and versions. Inside one project and its context all team members can play their respective roles by checking out pieces of the project. Time stamping and indication of user ids as well as location will help track who is doing what when. Tools analogous to PERT and CPM will be made available to project managers as well as virtual team members. However, these tools will be improved by the consideration of other dimensions, such as several layers to create a metaphor for the different teams. Cross-layer connections will create a difference that has not yet been implemented in current project management software for single projects. The guiding design principle for the cross layering is the ability to implement task dependence information across virtual projects, which are being performed in different layers of the software. In this way, we are able to include not only the traditional concept of task dependence within a project but also across different projects.

Even more importantly, the system will be designed to track knowledge, i.e., to provide a knowledge audit. This should be done in a way that is not perceived by the group members as invasive, but instead as helping them perform not only the tasks associated with this particular project but also other tasks that may come for future projects. In fact, this will be one of the ways in which knowledge will be transferred across time and across projects.

Part of the knowledge audit is the process of making tacit knowledge explicit. The traditional definition of tacit knowledge is knowledge that is only available in the minds of individuals (Nonaka & Takeuichi, 1995). Here, we are defining a second kind of tacit knowledge that is only available in the "time container" that is a particular project. To make this knowledge transcend the time boundaries of a project and be available for future projects as well is to make the knowledge organizationally explicit. In this way, the system takes care of making ideas explicit by keeping track of them and possibly generating categories, or “handles,” that simplify knowledge retrieval. This means there is no need to allocate time into the project budget for making a formal transfer of knowledge. That transfer is handled largely by the technological infrastructure.

Conclusion

In this paper, we strived to make a case for the connection between virtual project management and knowledge management. Although unlikely bedmates because of the difference in development cycle time, we showed that they indeed relate through the concepts of transferability and capacity of aggregation of knowledge. We proceeded to expand on this connection, with an emphasis on the areas where theoretical and practical development is more lacking. Research questions addressing these open spaces were developed, along with a general explanation of the research methodology for addressing the appropriate research questions. Finally, we elaborated on the technical infrastructure that will be needed to implement our vision of a system that will be able to answer some of the questions in this area.

The unique contribution of this paper is its focus on knowledge management as a cornerstone of virtual projects. The research framework provides a foundation for important questions to study, and points to key constructs whose operationalization will add value to this research area. The concepts of geographic dispersion and affiliation dispersion provide a new way to examine a *range* of differences across distance and organizations. Finally, the notions of knowledge transferability and aggregation provide a bridge for linking knowledge from projects across time and context. These foundational ideas provide ample opportunity for testing in a virtual engineering laboratory.

References

Chappell, D.A., Vogel, D.R., & Roberts, E.E. (1992). "The MIRROR project: A virtual meeting place," *Proceedings of the Twenty-Fifth Hawaii International Conference on System Sciences*, Hawaii, 23-33.

Checkland, P.B. & Soles, J. (1990). *Soft Systems Methodology in Action*. Chichester: John Wiley & Sons, Inc.

Cramton, C.D. (1997). "Information problems in dispersed teams," *Academy of Management Proceedings*, Boston, MA, 298-302.

Cramton, C.D, & Webber, S.S. (1999). "Modeling the impact of geographical dispersion on work teams," unpublished working paper, George Mason University, Fairfax, VA.

Davenport, T.H., & Prusak, L. (1998). *Working Knowledge: How Organizations Manage What They Know*, Boston, Massachusetts: Harvard Business School Press.

Deephouse, C., Mukhopadhyay, T., Goldenson, D.R., & Kellner, M.I. (1995-96). "Software processes and project performance. *Journal of Management Information Systems*, 12(3), 187-205.

Dennis, A.R., Pootheri, S.K., & Natarajan, V.L. (1998). "Lessons from the early adopters of web groupware," *Journal of Management Information Systems*, 14(4), 65-86.

DeSanctis, G., & Gallupe, R. B. (1987). "A foundation for the study of group decision support systems," *Management Science*, 33(5), 589-609.

Donnellon, A. Gray, B. & Bougon, M. G. (1986). "Communication, meaning and organized action," *Administrative Science Quarterly*, 31, 43-55.

Evaristo, J. R. & Fenema, P. (1999). "A typology of project management: emergence and evolution of new forms," *International Journal of Project Management.*

Galbraith, J.R. (1973). "Designing complex organizations," in Schein, E.H., Beckhard, R., & Bennis, W.G. (eds.), *Organizational Development*, Reading, Massachusetts: Addison-Wesley.

Ghoshal, S., & Bartlett, C.A. (1994). "Linking organizational context and managerial action: The dimensions of quality of management," *Strategic Management Journal*, 15, 91-112.

Ginsburg, M. & Kambil, A. (1999). "Annotate: A web-based knowledge management support system for document collections," *Proceedings of the 32nd Hawaii International Conference on System Sciences*, Maui, Hawaii.

Grant, R, M. (1996). “Toward a knowledge based theory of the firm,” *Strategic Management Journal*, 17, 109-122.

Hamilton, W.F., & Singh, H. (1992). “The evolution of corporate capabilities in emerging technologies,” *Interfaces*, 22(4), 13-23.

Hinds, P., & Kiesler, S. (1995). “Communication across boundaries: Work, structure, and use of communication technologies in a large organization,” *Organization Science*, 6(4), 373-393.

Jarvenpaa, S.L., & Ives, B. (1994). “The global network organization of the future: Information management opportunities and challenges,” *Journal of Management Information Systems*, 10(4), 25-57.

Jarvenpaa, S.L., Knoll, K., & Leidner, D.E. (1998). “Is anybody out there? Trust in global virtual teams,” *Journal of Management Information Systems*, 14(4), 29-64.

Kendall, J. & Kendall, K. (1993). “Metaphors and methodologies: living beyond the systems machine,” *MIS Quarterly*, 17(2), 149-171.

Kogut, B. & Zander, U. (1992). “Knowledge of the firm, combinative capabilities, and the replication of technology,” *Organization Studies*, 3, 383-397.

Lipnack, J. & Stamps, J. (1997). *Virtual Teams, Reaching Across Space, Time, and Organizations with Technology*. New York: John Wiley and Sons, Inc.

Nonaka, I. & Takeuichi, H. (1995). *The Knowledge Creating Company*. New York, NY: Oxford University Press.

Nunamaker, J.F. Dennis, A.R., Valacich, J.S., Vogel, D.R., & George, J. (1991). “Electronic meeting systems to support group work.” *Communications of the ACM*, *34*(7), 40-61.

Orlikowski, W. (1993). “Learning from Notes: Organizational issues in groupware implementation,” *The Information Society*, 9, 237-250.

Powell, T.C. (1993), “Firm-specific competitive advantage in high technology firms,” *Journal of High Technology Management*, 4(2), 197-209.

Qureshi, S., & Vogel, D. (1999). “Organisational challenges and research directions for distributed group support,” *Proceedings of the 32nd Hawaii International Conference on System Sciences*, Maui, Hawaii.

Romano, Jr., N.C., Nunamaker, Jr., J.F., Briggs, R.O., & Vogel, D.R. (1998). “Architecture, design, and development of an HTML/JavaScript web-based group support system," *Journal of the American Society for Information Science*, 49(7), 649-667.

Schein, E.H. (1984). "Coming to a new awareness of organizational culture," *Strategic Management Journal*, 25(1), 3-16.

Schwabe, G. (1999). "Understanding and supporting knowledge management and organizational memory in a city council, *Proceedings of the 32nd Hawaii International Conference on System Sciences*, Maui, Hawaii.

Sheetz, S., Tegarden, D., Kozar, K., & Zigurs, I. (1994). "A group support systems approach to cognitive mapping," *Journal of Management Information Systems*, 11(1), 31-57.

Shenhar, A.J. (1998). "From theory to practice: Toward a typology of project-management styles," *IEEE Transactions on Engineering Management*, 45(1), 33-48.

Simon, H.A. (1981). *The Sciences of the Artificial*, Cambridge: MIT Press.

Teece, D.J. (1988). "Capturing value from technological innovation: Integration, strategic partnering, and licensing decisions, *Interfaces*, 18(3), 46-61.

Teece, D. J. (1986). "Profiting from technological innovation: implications for integration, collaboration, licensing and public policy," *Research Policy*, 15, 285-305.

Tuomi, I. (1999). "Data is more than knowledge: Implications of the reversed knowledge hierarchy for knowledge management and organizational memory." *Proceedings of the 32nd Hawaii International Conference on System Sciences*, Maui, Hawaii

van Krogh, G., & Roos, J. (1992). "Figuring out your competence configuration," *European Management Journal*, 4, 422-427.

Ven der Merwe, A. (1997). "Multi-project management—Organization structure and control, *International Journal of Project Management*, 15(4), 223-233.

Warkentin, M.E., Sayeed, L., & Hightower, R. (1997). "Virtual teams versus face-to-face teams: An exploratory study of a web-based conference system," *Decision Sciences*, 28(4), 975-996.

Weick, K. & Meader, D. (1993). "Sensemaking and group support systems," in Jessup, L. & Valacich, J. (eds.), *Group Support Systems: New Perspectives*, New York, NY: Macmillan Publishing Company.