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USE OF COLLABORATIVE TECHNOLOGIES AND KNOWLEDGE SHARING IN CO-LOCATED AND DISTRIBUTED TEAMS: TOWARDS THE 24-HOUR KNOWLEDGE FACTORY

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ABSTRACT

The relocation of knowledge work to emerging countries is leading to an increasing use of Globally Distributed Teams (GDT) engaged in complex tasks. In the present study, we investigate a particular type of GDT working 'around the clock': the 24 hours knowledge factory (Gupta, 2008). Adopting the productivity perspective on knowledge sharing (Haas and Hansen, 2005, 2007), we develop 11 hypotheses to compare technology use, knowledge sharing processes, and performance of a 24 hours knowledge factory with a co-located team. We conducted a quasi-experiment in IBM and collected both quantitative and qualitative data, over a period of 12 months, on a GDT and a co-located team. Both teams were composed of the same number of professionals, provided with the same technologies, engaged in similar tasks, and given similar deadlines. We found that they differed in their use of technologies and in knowledge sharing processes, but not in efficiency and quality of outcomes. We show how the co-located team and the GDT enacted a knowledge codification strategy and a personalization strategy respectively; in each case, they grafted elements of the other strategy in order to attain both knowledge re-use and creativity. We conclude by discussing theoretical contributions to knowledge sharing and GDT literatures, and by highlighting managerial implications to those organizations interested in developing a fully functional 24 hour knowledge factory.

Keywords: Globally Distributed Teams, 24 hours knowledge factory, knowledge sharing

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INTRODUCTION

The relocation of knowledge work to emerging countries has been largely analyzed as a cost-savings driven phenomenon (Manning et al., 2008). Reports from the Association of Computer Machinery (ACM), the Institute of Electrical and Electronics Engineers (IEEE) and the National Society of Professional Engineers (NSPE) have described offshoring in the context of jobs being gained or lost due to cost savings between nations like in a competitive zero-sum situation, where work can only be done in one country or the other (IEEE, 2004; White, 2004; Asprey,et al., 2006).

Research in organizational theory, strategy, and psychology reinforces the idea that knowledge work, such as product development, can be done most productively in a single location. For instance, Thompson's (1967: 54-61) early work on structural contingency theory posited that activities like product development create reciprocal interdependence between individuals and subunits. Reciprocal interdependence is most effectively managed by locating individuals in close proximity to facilitate high levels of communication between them. Similarly, transaction cost theorists have suggested that knowledge work, such as information technology development, is best performed internally due to concerns over the loss of control over work (Loh and Venkatraman, 1995), high transaction costs (Ang and Straub, 1998), and threat of knowledge loss (Duncan, 1998) when knowledge work is outsourced. Finally, studies on inter-personal communication have shown that geographic distance reduces the opportunity for face-to-face interaction (Conrath, 1973), which is necessary for transferring tacit knowledge between individuals and organizations (Porter, 1998; Sternberg, 1991; Tallman et al., 2004).

Traditionally, physical distance was considered detrimental to inter-personal and inter-organizational collaboration, which is why many firms in the 1980's and 1990's preferred co-locating large cross-functional teams at a single site (Eppinger and Chitkara, 2006).

However, recent advances in information technology have enabled virtual distributed teams to perform knowledge work effectively without meeting face-to-face (Cummings, 2004; Mazneski and Chudoba, 2000). By virtual teams, we mean groups of workers who are geographically and temporally dispersed and are assembled via technology to accomplish an organizational task (Jarvenpaa et al., 1998; Lipnack and Stamps, 1997). When virtual teams are based in different countries, they are referred to as GDTs, i.e. Globally Distributed Teams. The rich and vibrant body of research on virtual teams and GDTs (Cohen and Gibson, 2003), and the increasing reliance of organizations on virtual teams in diverse activities such as research and development laboratories (Brockhoff, 1998), IS development (Chakrabarti, 2006), and software development (Carmel, 1999) suggest the potential for a new model of distributed knowledge production that can leverage geographic distance for strategic advantage.

Over time, the view of offshoring as primarily a cost saving exercise has gradually transitioned to a perspective that views offshoring as a mechanism for utilizing a globally distributed workforce in a new manner made possible by advances in information systems (Venkatraman, 2004; Cullen et al., 2005; Walsham, 2005; Manning et al., 2008; Gupta, 2008). And while this development may seem obvious to managers of organizations practicing the model described in this paper, the academic literature contains many gaps in our knowledge about the functioning and performance of virtual teams in a distributed knowledge work environment. For instance, while there has been a considerable amount of research on interpersonal issues such as conflict, trust, and identity in virtual teams (Jarvenpaa et al., 1998;

Jarvenpaa and Leidner, 1999. Montoya-Weiss et al., 2001; Cramton and Hinds, 2005; Hinds and Mortensen, 2005), there has been less research on the use of tools and methods in distributed teams when increased handoffs between team members exist; the same void exists for analyzing the conditions under which the use of such tools can improve the effectiveness of the distributed model, and in understanding how differently structured GDTs actually work (O'Leary and Cummings, 2007). In addition, one common criticism of research on globally distributed teams is the lack of extended field experiments -- conducted in commercial environments -- that have compared the behaviors of co-located and distributed teams and how these behaviors are related to the performance of the distributed model. These issues are important for understanding the effective management of geographically distributed teams: how can distributed teams work effectively with frequent transfer (handoffs) of work-in-progress with each other?; how can subsets of team members work during daytime in their respective countries and still achieve round-the-clock operation for the entire team?; and how effective can geographically distributed teams be in comparison to collocated teams?

In this paper, we advance our knowledge of globally distributed teams by conducting a field study that compares the collaboration activities between members of a globally distributed team with the collaboration activities between co-located team members performing a similar task. Here, we consider offshoring in a mutually beneficial perspective where the interests of workers in high-income economies are aligned with workers in other countries and customers worldwide. The research question that guides this research is: in a commercial setting how do distributed and co-located teams performing the same task differ in their patterns of communication and knowledge sharing, and in their performance? In investigating this issue, we use the productivity perspective on knowledge sharing in organizations proposed by Haas and Hansen (2005, 2007).

Specifically, our focus will be on one type of globally distributed team, i.e., the 24-hour knowledge factory model (Gupta and Seshasai, 2007), which advocates continuous work on knowledge-based tasks by individuals located in time zones that allow for 24-hour engagement. Each individual in such work environments work the normal workday hours that pertain to his or her local time zone, and then pass the task to fellow workers located in a different time zone.

Our setting is a case study of a two-site, global work environment (in contrast to a fully localized work arrangement); we believe that the insights gained from examining this case study can serve as the basis for analyzing the characteristics of true 24-hour knowledge factories that are rapidly evolving in different industries.

This paper is organized as follows: first, we introduce the concept of the 24-hour knowledge factory; then we discuss the productivity perspective on knowledge sharing and develop hypotheses. After describing the methodology followed to conduct our longitudinal field experiment of two teams (one co-located and one distributed), we present our results and conclude with a reflection on the theoretical and practical contributions of our study.

A SPECIFIC TYPE OF GLOBALLY DISTRIBUTED TEAM: THE 24-HOUR KNOWLEDGE FACTORY

We begin by providing a definition of a knowledge factory. A knowledge factory is defined as a collection of knowledge-driven workers tasked with producing a knowledge-based asset, with the workers frequently creating incremental assets that are handed off (i.e. passed back and forth) among fellow workers. A globally distributed call center is, in some ways, a knowledge factory because when calls are handled, the knowledge pertaining to the particular call is stored centrally and is available to the next individual who has to handle the same topic or the same caller. The software test and fix cycle environment is another knowledge factory in which software is the knowledge-based asset, and the knowledge of whether the software accomplishes its function is passed back and forth between software developers and testers. The 24-hour aspect, mentioned above, can be considered to be a manifestation of a knowledge factory where work is performed on a continuous basis around the clock. This structure allows for tasks to be executed with faster turnaround time, which is one of the major potential benefits of distributing work across time zones (Gupta, 2009b; Treinen and Miller-Frost, 2006; see also Eppinger and Chitkara, 2006; Majchrzak et al., 2000).

Understanding the implications of spatial and temporal separations between workers on the overall performance of the 24-Hour Knowledge Factory paradigm requires looking at the historical precedents of this model as well as analyzing a number of interrelated technical, strategic, organizational, and economic issues. The notion of shifts can be traced back to the industrial revolution. Since installed manufacturing equipment was scarce and costly, different sets of employees were scheduled to work in successive shifts so that the manufacturing facilities could be used on a round-the-clock basis. The use of the 8-hour shift system evolved over time. Initially, each worker was directed to work 12-16 hours a day so that all machines could be used for extended periods of time. Then, the notion of having two shifts evolved. Based on new legislation on both sides of the Atlantic, the work hours were gradually reduced. The introduction of the shift system yielded benefits in terms of higher productivity of each machine, reduced production times, and lower prices to customers. However, it also created social and health issues by requiring people to work in an urban setting, usually away from other members of their families, and also at odd hours and changing work schedules determined by the idiosyncrasies managers in charge of assigning workers to different shifts.

Global workforces provide firms with access to high-talent designers; however, in the absence of the 24-Hour Knowledge Factory model, these workers would need to relocate to a different country, or work at odd hours of the night, often referred to as the “graveyard shift”, in order to collaborate in real time with their globally distributed co-workers (Gupta, 2009a). Historically, observers from around the world deemed the time difference between globally distributed workers to be a major impediment when implementing distributed information systems. Recently, the perception has switched around; for many projects, the time difference is viewed as a strategic plus (Gupta, 2008). However, both views of the effectiveness of globally distributed teams are based on largely untested assumptions regarding the nature of work by co-located and distributed teams and the feasibility of handing off tasks across shifts.

The knowledge factory examined in this paper is set in the computer software industry. Here R&D teams are characterized by a development cycle that relies heavily on sequential performance of specific functions, such as development, testing, and verification. In a traditional software development environment, where all parties are located in the same geographic location, a code developer typically waits until a fully functional portion of the product is available before passing it on to an engineer to test it. However with the potential for receiving testing feedback overnight, the developer in a 24-hour knowledge factory model now has the unprecedented opportunity to build portions of the product on a daily basis (Treinen and Miller-Frost, 2006). Examples of collaborative technologies that enable the 24 hours knowledge factory in the software industry are general technologies (e.g., emails) and software specific technologies, such as software problem reports system and source code control systems.

Previous research has acknowledged that coordination and knowledge sharing across time and space during hand offs are critical in the 24 hour knowledge factory model (Gupta and

Seshasai, 2007). This is perhaps why this approach is not yet in widespread use (Espinosa and Carmel, 2003; Treinen and Miller-Frost, 2006). Most of the existing applications of the model are in fact based on two shifts. Nevertheless, the potential importance of a full application of the model calls for more studies about the challenges that the 24-hour factory model poses and how to overcome them.

COMMUNICATION, KNOWLEDGE SHARING, AND PERFORMANCE: DEVELOPMENT OF HYPOTHESES

Effective knowledge sharing is considered essential for high performance in both co-located and distributed settings (Cummings, 2004; Tagliaventi and Mattarelli, 2006; Kotlarsky et al., 2008). Haas and Hansen (2007) outlined two distinct ways of sharing knowledge: through written documents that are made available in paper or in electronic format, and through direct contact between individuals. Accordingly, two different knowledge management strategies can be applied in organizational contexts: codification and personalization (Hansen et al., 1999). Teams that adopt a codification strategy ‘automate’ knowledge management; they make use of information and communication technologies to codify and store knowledge into databases, with the objective of re-using codified knowledge in a ‘people-to-documents’ fashion. Teams that adopt a personalization strategy rely on individual members to share knowledge and develop networks where tacit knowledge can be shared on a person-to-person basis.

In two studies of co-located consultancy teams, Haas and Hansen (2005, 2007) introduced the productivity perspective on knowledge sharing, based on the idea that different types of knowledge sharing affect task performance dimensions differently. For instance, they found that the level of quality of electronic documents’ used directly affects the time saved on tasks, but only indirectly affects the quality of team output. At the same time, personal advice from external members favors the quality of work but is not linked to the timely responses of the team.

In this paper, we adopt the productivity perspective framework and extend it to the case of globally distributed teams and the 24-hour knowledge factory. Specifically, for software development teams, the use of collaborative technologies (e.g., source code system) is essential for their functioning in both collocated and distributed settings. At the same time, the different perceptions and experiences of team members may induce ways of using the collaborative technologies differently from what was originally expected. Users may adopt a collaborative technology, ignoring part of its properties or inventing new ones, going the extra mile or contradicting the requirements of its original design (Orlikowski, 2000). Technologies, in fact, do not exist in the abstract, but are manifest only when one introduces them into a social network, where they are necessarily subject to re-definition and re-structuring (Friedberg, 1993; Crozier and Friedberg, 1994).

Thus, even though in distributed settings the use of collaborative technologies is expected to be more intense (Lipnack and Stamps, 1997; Maznewski and Chudoba, 2000), it must be recognized that some informal person-to-person practices for sharing tacit knowledge will still emerge (Kotlarsky and Oshri, 2005; Oshri et al., 2007; Mattarelli and Gupta, 2009). In other words, given the same set of communication technologies, we expect that co-located and distributed teams will develop different strategies for sharing codified and tacit knowledge, as well as a different mix of 'codification' and 'personalization' practices. Given this premise, we develop a comparative framework of distributed and co-located teams based on the constructs depicted in Figure 1.

INSERT FIGURE 1 ABOUT HERE

Technology use and patterns of communication

There has long been a sense that face-to-face interaction can facilitate creative interaction and produce more and better ideas (Osborn, 1957). However, there is an equally long history of experimental findings that show that the aggregate output of so-called “nominal” or “concocted” groups of individuals working alone outstrips the aggregate output of “real” groups of the same number of individuals working together in person on creative tasks such as idea generation (Lorge et al., 1958; Mullen et al., 1991; Taylor et al., 1958). Real interactive groups consistently incur a “process loss” during group interaction that nominal groups avoid (Steiner, 1972). The inability of all real group members to contribute their ideas simultaneously can create a bottleneck that blocks potentially valuable contributions from some members and thereby reduces the effectiveness of real groups (Diehl and Stroebe, 1987; 1991).

A number of researchers have noted that the use of communication technology can enhance the performance of both real and nominal teams (e.g., members working more independently than collaboratively). For instance, the use of information technology tools by real interactive groups can simultaneously enable creative production and removal of social inhibition, thereby eliminating the production blocking problem (Paulus et al. 1996; McLeod et al., 1997). As a result, real groups can sometimes be even more productive than nominal groups (Dennis and Valacich 1993; Valacich et al., 1994). Globally distributed teams share key characteristics with nominal groups and also with electronic interacting groups (team member interaction mediated by technology). The social psychology literature on small group dynamics implies that global virtual teams may enjoy certain advantages relative to collocated teams (e.g., Krikman et al., 2004), and with the aid of electronic communication, the advantage of distributed teams over co-located interactive teams grows even further as group size increases (Gallupe et al., 1992).

One issue that has not been suitably addressed by this literature is how co-located and distributed teams differ in their use of technologies. In globally distributed teams, especially when time differences separate participants, the occasions for synchronous communications to discuss task-relevant issues are reduced. Moreover, such teams 'will be more likely to transfer knowledge in explicit rather than tacit forms because the technology supports the declarative nature of explicit knowledge' (Griffith et al., 2003, p. 271). This means that, given a set of collaborative technologies provided to the team, if a team is characterized by higher 'virtualness' (in terms of geographic and temporal separation), it will also rely more on codified and 'written' forms of communication to discuss issues that are relevant to the completion of tasks. Thus, if we compare a GDT with a co-localized team, we can hypothesize that:

HP 1: The distributed team will rely more heavily, than the co-located team, on written communication for team discussion.

Among the different types of collaborative technologies, emails are probably the most widespread and diffused. In the workplace, emails are used both for formal and informal communications. In the first case, emails represent a way to assess the state of work, share formal documents, define meetings; in other words, they belong to the codification strategy described above. In the second case, emails are used for quick and informal messages, in addition to other means of communication (e.g., face to face, instant messaging), coherently with a personalization strategy (Hansen et al., 1999). As such, we expect that many messages of the second type will be sent when team members are co-located in the same time zone and have other means of synchronous communication. On the other hand, when team members are globally distributed and separated by time and space, the former use is preferred and fewer emails are exchanged. Thus, we hypothesize that:

HP 2: The distributed team will rely less, than the co-located team, on broadcast style email messages.

Consistent with what was discussed above, we expect that distributed teams will use emails mainly as a codification strategy. This means that emails will contain detailed discussions that team members would not be otherwise able to conduct and formalize, given the time difference across sites. Thus, it follows that:

HP 3: The distributed team will conduct longer discussions, than the co-located team, primarily in written (email) form.

Among the different types of content of emails, logistical messages are those related to a specific task or action to be completed in very short time (e.g., less than a week's time). A logistical message is focused on logistics of a specific action and the language is very focused, as opposed to a message that is trying to gather a broader set of opinions. Accordingly, logistical messages can be interpreted as informal reminders that team members share in order to synchronize their pace, when they work in the same time zone. But, when team members are separated, a schedule of activities and work is defined in advance (Carmel, 1999) and thus, we expect that:

HP 4: The distributed team will send fewer logistical messages, than the co-located team, to members of the group.

Knowledge sharing

While electronic communication tools, such as email, allow distributed teams to work interactively (to some extent) and productively on creative tasks, they do not resolve the challenge of tacit knowledge, which is considered to be essential to innovative activities but is difficult to transfer without face-to-face interaction (Kogut and Zander 1992; Nonaka et al., 2000; Sternberg et al., 2000). The accessibility of ambient tacit knowledge has been posited as a major reason firms locate in close geographic proximity to other organizations within the same industry (Audretsch and Stephan, 1996; Porter, 1998; Rosenfeld, 1997; Tallman et al., 2004). If correct, globally distributed teams may be missing a key ingredient that would help them function effectively, suggesting that co-located product development teams may be preferable after all.

The logic underlying the following hypotheses is based on the notion that a globally distributed team requires more handoffs of knowledge, and thus requires more formal systems to facilitate these handoffs (Mattarelli and Gupta, 2009). Accordingly, the distributed team adapts the technical design and processes to reduce the number of interactions required. This has an impact on the nature of discussions, the nature of tasks, and the nature of assigning technical modules, as described in the hypotheses.

Among the technical design and processes used by software development teams, of particular relevance is the source code modification process: a computer-based system for logging changes made to the computer programs being developed by the team. When programming, team members must consider the "feature freeze" date, i.e. the deadline to complete programming work, other required tasks, and all features within the given software release. Consistent with a codification perspective, we expect that distributed teams will make major use of the source code modification process when approaching the deadline of the feature freeze date in order to translate tacit knowledge into easily sharable codified knowledge (Griffith et al., 2003). For example, the individuals on the distributed team may each commit the source code changes they are responsible for into the system before discussing with other individuals. On the other hand, members of the co-located team would discuss a particular code modification before committing it to the project. In other words, co-located team members will rely more on informal contacts and discussions in order to share tacit knowledge about the product. Thus, we expect:

HP 5: The distributed team, as compared with the co-located team, will make greater use of the source code modification process to resolve issues, in place of informal collaboration, before the 'feature freeze' date.

When working on software development, teams are assigned different modules. A team may decide to have a single person to take care of each module or to have multiple individuals working together on each module. In the latter case, the socio-technical system is more interconnected, because two or more individuals associated with the same module must share and build tacit and codified knowledge through repeated interactions. Consistent with a codification strategy, and with the perspective that members of virtual teams are less likely to acquire tacit knowledge from their distant teammates (Griffith et al., 2003), we expect that:

HP 6: The socio-technical system of the distributed team will be less interconnected as compared to the co-located team.

Knowledge sharing among team members also occurs through the mechanism of meetings. Periodic meetings are considered to be fundamental for the proper functioning of co-located and distributed teams (Hackman, 1990; Kiesler and Cummings, 2002; Ganesan et al., 2005). Meetings can be face to face, through videoconference, or by phone. They can deal with long term strategic decisions, such as the technical architecture of the product or with short term tactical issues, such as the discussion of the specific content of work tasks (e.g., if a piece of coding is better done in one way versus another).

Logically, co-located teams have the opportunity to discuss day-to-day tactical decisions in informal ways, for instance through a chat in the hallway or in front of the coffee machine. This is not possible for globally distributed teams separated by physical distance and time. Thus, in the latter case, formal meetings become necessary for both strategic and tactical decisions and the latter become the most frequent rationale. We can hypothesis that:

HP 7: The distributed team will rely more, than the co-located team, on meetings for handling short term issues.

Also, meetings can be organized to assign tasks to team members according to their expertise (Hackman, 1990). We expect that distributed teams will make more use of meetings to formalize task assignments, consistent with hypothesis 7. On the other hand, task assignment is done mainly informally and through face to face coordination in co-located settings.

HP 8: The distributed team is more likely than the co-located team to formally assign team member tasks in meeting format.

Finally, when it comes to the overall knowledge management strategy, the above discussion suggests that distributed teams will establish a codification strategy. In other words, given the same set of collaborative technologies, distributed teams will rely more on relevant technologies to codify knowledge and make this knowledge available to all team members.

HP 9: The distributed team will rely more on formal systems for knowledge capture, as compared to the co-located team.

Performance

Previous studies provide contradictory advantages and disadvantages for distributed and co-located teams, making it difficult to formulate general predictions about how each type of team would perform on a similar product development task. But, in the case of a team that has the time to develop trust and acquaintance of working together (e.g., a software development team whose members work together on a project for one year), it has been found that some of the limits of distribution are overcome and that a distributed team can produce an output similar to that of the traditional co-located team (Dennis and Garfield, 2003; Espinosa et al., 2003). In other words for long-term teams, the following hypothesis is likely:

HP 10: The output of the distributed team will be similar, in terms of quality, as that of the co-located team.

However, several studies have shown that the overall efficiency, generally defined as a measure of output from production processes per unit of input, of a distributed team is lower than that of a co-located one (e.g., Montoya-Weiss et al., 2001; Powell et al., 2004; Hightower et al, 2007). In the case of a team working on a 24 hours knowledge factory basis, efficiency is reduced by the overhead involved in transferring tasks back and forth on an incremental basis. Thus, we hypothesize that:

HP 11: The efficiency of the distributed team will be lower than that of the co-located team

METHOD

While several studies have investigated some of the differences between co-located and distributed work in laboratory settings, limited empirical evidence has been collected in real world settings, especially when teams are globally distributed (McGrath, 1991; Montoya-Weiss *et al.*, 2001; Massey et al., 2003; Martins et al., 2004). Moreover, extant work tends to treat all virtual teams alike (Bell and Kozlowski, 2002), while in practice, virtual teams may differ significantly from one another in terms of their structure, duration, and tasks (Saunders and Ahuja, 2006; O'Leary and Cummings, 2007). On a related note, significant empirical research has been performed using cross-sectional surveys of hundreds of teams (e.g., Cummings 2004).

A notable exception to the mainstream literature on virtual teams is provided by the exemplar work of Majchrzak and colleagues (2000), who studied a product development team that was distributed across three organizations in different locations and collected longitudinal ethnographic and quantitative data to develop an in-depth understanding of the operation of the team from social, organizational, and technical perspectives.

Inspired by this type of in-depth data collection strategy, a longitudinal study of co-located and distributed software development teams was conducted at IBM Corporation. We compared two teams within a single firm and we manipulated the key variable of organizational structure (geographic distribution). One team was entirely based in Boston, MA, while a second team was distributed between Boston and Bangalore (India). In contrast to descriptive case studies, the present study is a controlled field experiment that compares two teams with nearly identical characteristics except for the critical variable of interest: co-location versus geographic distribution of team members. The design is a "quasi-experiment" (Cook and Campbell, 1979) in the sense that team members were not randomly assigned to each type of team, but the twin features of similar composition of team and exercise of controls for other possible explanatory factors allowed us to infer that the difference in the structure of the two teams was the basis for observed differences in team performance.

In the following sub-sections, we describe the characteristics of the two teams, the data sources used, and the data analysis process followed, and the measures used to test the hypotheses.

Team characteristics

Both teams belonged to IBM and worked within the department responsible for building new collaborative software. The two teams worked on two parts of the same software package, with one team producing a document management product and the other producing a team collaboration product. The two teams were subject to identical time schedules (12 months) and deadlines, and were under the same environment in terms of project management, resources, and work rules. Teams were provided with the same collaborative technologies: an email system, an instant messaging system, and the same processes for managing tasks and source code.

Each team was assigned 7 members (3 in the US and 4 in India for the distributed team) with similar positions, qualifications and experience. Of the 7 team members, 1 was the lead, 6 were developers, each with 5 to 20 years experience and seniority. The average professional and organizational tenures for the co-located and distributed teams were both approximately 10 years.

All the co-located team members worked on the software during the same work hours, whereas the globally distributed team members shifted work back and forth across time zones in an asynchronous manner. The two sequential work shifts of the distributed team provide less coverage than the three consecutive 8-hour work shifts in the ideal 24-hour knowledge factory model, but dispersion of the team across 10 time zones forced team members to work more independently during their respective shifts, providing a conservative test of the key feature of the model.

Data sources and analysis

Quantitative and qualitative data were collected systematically from the two teams over a period of one full calendar year. Since the main project deliverable was on a one-year timeframe, this period covered every major point in the project lifecycle from the kick-off to the delivery of the end product. Within this year, the teams devoted a significant amount of time to short-term tasks such as attending to customer deployment issues and fixing bugs for maintenance releases;

as such, the one-year timeframe provided an opportunity to gain insights on knowledge sharing for multiple scopes and varieties of tasks. The data collection process was designed to provide a complete picture of the knowledge sharing that occurred over the one-year period in terms of technical, organizational, social, and group process dimensions. The experimental design and quantitative measures enabled direct comparisons between the co-located and distributed groups on the key dimensions of interest. The data sources employed were: interviews, observations of weekly meetings, and archival data. They are described below.

Interviews: Two hour-long structured interviews (Gubrium and Holstein, 1995) were conducted with each of the developers on each team. While the focus of these interviews was primarily to gain qualitative insight on work content, specific quantitative questions were asked in order to elicit the developers' own views of their knowledge sharing requirements. In particular, interviewees were asked to elucidate about and provide the number of: informal interactions (i.e., interactions that did not begin with an intention of discussing business) with fellow team members and with main developers; formal interactions with main developers; informal communication in person, via instant messaging, and via phone; tactical decisions made informally (decisions that were minor in scope, with minimal knowledge sharing requirements and minimal impact on other developers' work); strategic decisions made informally (decisions that were major in scope, with significant knowledge sharing requirements and long-term impact on other developers' work); strategic decisions that were speeded up informally; and tactical decisions that were speeded up informally. Interviews were transcribed into files and inductively coded to obtain the quantitative measures described below.

Observations of Weekly Meetings: The weekly meetings of each team were observed (in Boston) by one of the authors to gain insights into the processes of formal task allocation and knowledge sharing, on a group-wide basis, for each team. The teams organized three meetings per week (one meeting for co-located team, one meeting for U.S. team members of the distributed U.S.-India team, and one U.S.-India team joint session). The subgroup in India did not hold formal meetings, because the project manager was a US-based employee and only ran meetings which involved US-based employees in the US time zone. The Indian subgroup members sat next to each other, and would often discuss items, but did not have a formal meeting.

The minutes were recorded by the project manager for the teams, who maintained item-by-item details of the discussion and shared them with the researchers. The co-located team held one face-to-face team-wide meeting per week, while the distributed team held one weekly face-to-face meeting for only the U.S.-based team members and one weekly coordination meeting via telephone between the development leads from the U.S. and India.

Minutes were inductively coded to obtain quantitative measures such as: the number of Tactical Tasks Assigned, the number of Strategic Tasks Assigned, the number of Tactical Status Requests, the number of Strategic Status Requests. Tasks are defined as future actions required of a team member while status requests are queries on past actions. Tactical refers to a very specific scope with a definitive action, and strategic refers to a more broadly scoped question without a specific action.

Archival Data: Three types of archival data were used. First, each development team kept track of fixes requested or made to the code base via Software Problem Reports (SPRs). These SPRs contained information on the problem being reported, as well as the history of knowledge provided by various developers in resolving the issue and information regarding the actual fix to the issue. SPRs were stored in a central database for each team. Modifications to SPR states were performed according to a formalized process. The formalized process of storing, tracking, and transforming SPRs, from their creation to problem resolution, constituted a formalized knowledge capture system. For purposes of this study, a software tool was written to collect the data from the SPR archive. This tool analyzed the software problems that were resolved over the 12-month period of study, and collected the specific types of data (e.g., average delay between developer inputs) for each developer, on a weekly basis. The measures used in the analysis are described in the next sub-section.

Second, each of the two teams used a source control system to log the modifications made to each element of the source code for the team's product. The source control system stored the date, time, developer making the change, and a comment regarding the particular change. The comments often cited particular SPRs if there was an SPR that initiated the particular change to be made. The goal of collecting data from the source control system was to ensure a clear depiction of the technical system, which would complement the social and organizational systems described by the other forms of data that were collected. The data from the source control system provided a representation of the technical dependencies between developers on the teams, and the rate of technical collaboration within the teams. Different data were collected, with respect to each developer, on a weekly basis (e.g., Delay between check-ins). The measures used in the analysis are described in next sub-section.

Finally, a software tool was written to analyze e-mail messages sent to all members of each team. A "thread" refers to the entire set of messages written in response to an initial electronic broadcast or request for information. These data provided insights into the use of broadcast messages to share knowledge on the teams. Different data were collected, with respect to each developer, on a weekly basis (e.g., number of threads contributed to). Moreover, email messages were coded, according to their content, into logistical and non-logistical messages.

Measures

The measures of the variables used to test the hypotheses of this study (derived from the data sources described above) are shown in column 2 of Table 1. Specifically, data derived from observations of meetings, and the hypotheses to which they applied, were as follows:

- the fraction of tactical (versus strategic) meeting items as a proxy of the discussion of short term issues during meetings (HP 7);
- the percent of task assignment (versus status) meeting agenda items as a proxy of the use of meetings for task assignment (HP 8).

From SPR data, the following were derived:

- the number of source code check-ins prior to deadline in week 41 as a proxy of use of source code modification processes (HP 5);
- the average SPR time to resolution, that is the average time it takes for an SPR to move from being approved by the management team to being fixed, and finally to actually being logged as fixed, as a proxy of team efficiency (HP 11).

From source control system data, we derived:

- the number of individuals working on each module as a proxy of the interconnection of the socio-technical systems (HP 6)
- the average number of individuals modifying SPR state– The number of individuals modifying SPR state corresponds to the number of people who were directly involved in resolving a particular problem relying on the formal system of knowledge capture; thus, it is a proxy of reliance on formal systems of knowledge capture. (HP 9)

- the average number of SPR actions per week – The larger the number the SPR actions, the greater is the number of software problems that were reported. Hence it is a proxy for output quality (HP 10); actually, the number of SPR is inversely related to software quality.

Finally, from the analysis of email messages, we derived:

- the number of contributions per email thread, as a proxy of amount of written communication (HP 1);
- the average weekly email thread initiated, as a proxy of the amount of broadcast style email messages (HP 2);
- the average length of initiated threads as a proxy of length of discussions in written form (HP 3);
- the average number of logistical weekly emails as a proxy of intensity of logistical messages (HP 4).

RESULTS

Quantitative analysis

Comparisons of outcomes for the key process variables for the distributed and collocated teams are presented in Table 1, based on the set of 11 hypotheses formulated earlier in the paper. The table contains means and standard deviations of each observed variable. Additionally, a t test was used to compare means across groups and validate the formulated hypotheses.

No statistical difference was found for HP 1; the two teams did not differ in terms of the number of contributors per email thread. This may be explained by the small size of the team (7 members) and by the similar division of labor across the two teams.

However, consistent with HP 2 and HP 4, our data revealed that the number of email threads initiated and the number of logistical emails sent per week are significantly larger for the co-located team than for distributed team. In other words, the co-located team communicated more frequently via email messages than did members of the globally distributed team; this was despite the fact that many of the co-located team members worked in the same hallway of the same building. Though it appears that the number of email threads initiated is larger for co-located teams, it should be noted that the number of emails exchanged within each initiated thread does not change significantly across the two teams (thus disproving HP 3).

The two teams differed most dramatically in the number of source code modifications prior to the "feature freeze" deadline in week 41, with the distributed team making 53.8 modifications compared to only 11.6 modifications by the co-located team ($t = 3{,}93$, $p < 0{,}05$). In other words, the co-located team was able to approach a key product development deadline with much fewer last-minute changes, and its work on the software code involved more person to person consultation than the work by the globally distributed team. This supports HP 5.

On average, there were more developers per code element for the co-located team, as compared to the distributed team, thereby supporting HP 6. This is consistent with the consideration that the socio-technical system of the distributed team is less interconnected than the co-located one.

Consistent with HP 7, HP 8, and HP 9 which were all validated by the case study, the two teams used team meetings for very different purposes; the meetings of the distributed team featured a significantly higher percentage of tactical (cf. strategic) agenda items (HP 7) and also a much higher percentage of assignment items (cf. status items, HP 8). Overall, the distributed team relied more on formal systems for knowledge capture, as evidenced by the intensity of use of SPR (HP 9).

We found support for HP 10, but not for HP 11. In other words, both the output quality and efficiency (measured by weekly SPR actions and average time to resolve SPR's, respectively) of the two teams were similar. This means that, despite the very different usage of information systems and meeting behaviors, each team exhibited similar performance in terms of the quality and speed of their work.   In the next section, we triangulate the quantitative results with our qualitative evidence.

INSERT TABLE 1 ABOUT HERE

Qualitative analysis

Qualitative data from interviews and meetings helped us in understanding more deeply the context under study, in triangulating the evidence from the quantitative data, and in adding insights on the underlying processes. In the following paragraphs, we present the perceptions of our informants on i) technology use and knowledge sharing; ii) the link between social relationship and technical behavior; iii) the outputs of distributed and co-located teams; and iv) the major advantages of geographic distribution.

Technology use and knowledge sharing processes are enacted differently

Our quantitative evidence shows that, while the two teams were provided with the same technologies, their use and the consequent knowledge sharing processes enacted very differently. For instance, the distributed team was more parsimonious in the use of emails. During interviews, members of the globally distributed team confirmed that they used emails for specific large scale purposes, and not to address short term issues related to the advancement of work. In other words, GDT members used email messages as part of the codification strategy (Hansen at al., 1999) and to extend the knowledge capture processes guaranteed by the SPR. On the other hand, co-located team members used email messages in a more informal fashion, even with few lines and short logistical questions. In other words, email messages were perceived to be a continuation of face to face interactions.

It is also evident that the distributed team relied more on the source code system to manage the modification of software and on formal knowledge capture systems to codify all the knowledge produced by the team. Specifically, distributed team members affirmed that they used this technology as a means of transferring information and knowledge between team members and maintaining a record of status, while the co-located team members affirmed that they could rely on synchronous communication for purposes of information sharing and status reporting. Interviews with GDT members also highlighted that the use of formal systems increased individual confidence in team results and improved the management of physical and temporal distance across team members.

Also, the nature of the meetings differed in the two cases. An analysis of the minutes of the meetings revealed that while the agenda categories were generally the same between meetings, the number of tactical items and number of task assignments were much higher in the case of the distributed team. In other words, meetings were used by distributed members to keep updated on individual work details and to redefine the workload assigned to each developer (see also Orlikowski and Yates, 2002). These two issues were not perceived as being of primary importance by co-located members, who could informally discuss such issues in the hallway or with a word over the cubicle, outside of the context of the formal weekly meetings.

Overall, these differences suggest that technology and processes that support knowledge sharing can be used to explicitly serve different purposes (cf. Maznevski and Chudoba 2000; Haas and Hansen, 2007). Barley (1986) provides a framework for assessing the role of technology in a knowledge-based work environment and suggests that the context in which the work is performed can significantly impact the way the technology is used. Teams will gradually adapt available technologies to suit their specific spatial and temporal structures.

Social relationships and technical behavior are linked

HP 6 was confirmed, highlighting that the co-located team had more examples of code elements that were modified by multiple team members; interviews confirmed that this was because of the greater degree of social interaction on this team, rather than any piece of software requiring more intertwined technical interaction than the other. The interview sessions also revealed many cases where casual interactions led to technical decisions. For instance, one of the developers stated: "While such social relationships are much easier to form when the team is co-located, the experience of one U.S. developer on the distributed team who traveled to India suggests that social relationships can be built across distant geographic and cultural boundaries and these relationships can be leveraged to satisfy technical goals."

Based on the above, the degree of social interaction between developers on a team was shown to have an impact on the technical behavior of the team, which then led to tighter social relationships. Developers on both teams cited the comfort level between team members as being important in facilitating creative discussions, so that developers did not have to worry about feeling embarrassed by a poor idea.

Geographic structure does not define output

The geographic structure of the teams in this study led to different forms of value being achieved from their knowledge sharing processes; however, it does not follow that the output of each team is necessarily defined by its structure. The structure of the distributed team led its members to have a higher degree of documented decisions. Interviews with members of the distributed team confirmed that a very valuable, though perhaps unintended, outcome of this documentation process was that the history of the decision making process of the team was better retained. On the other hand, the co-located team cited more frequent informal communications as a process that led to higher incidence of finding new and creative solutions. Even though these informal meetings generally occurred face-to-face, the distributed team could still achieve a similar outcome. During interviews on this specific topic, distributed team members mentioned the importance of a one-time face-to-face meeting that would introduce team members and incorporate a social component to the relationships, and the use of explicitly informal phone calls where no agenda or topic was preplanned so that team members could discuss any open-ended topic.

It is worth noting that co-located team members did not let unacknowledged the importance of documented processes, especially those related to decision making. During interviews on this specific topic, co-located team members mentioned on the one hand the importance of scheduling some midpoints in which each team member should put effort in codification and, on the other hand, the usefulness of automated tools to facilitate such processes.

Advantages of geographic distribution

Based on the analysis of the data from the interviews, Table 2 summarizes the major advantages of globally distributed and co-located teams. Our finding that both co-located and geographically distributed teams were capable of successful collaboration suggests that common themes in the literatures on offshoring (offshoring is a win-lose zero-sum proposition), innovation (geographic distribution is a barrier to overcome) and social and organizational psychology (face-to-face groups are more productive) may all be inaccurate. Numerous benefits from leveraging a dispersed geographic structure were cited in interviews with the distributed team. Examples include: an increase in documentation and history retention; enhanced ability to share short-term tasks which required immediate attention so that work could be performed around the clock; and a more structured and explicit definition of work tasks and distribution of work items.

INSERT TABLE 2 ABOUT HERE

DISCUSSION

A productivity perspective on knowledge sharing in globally distributed teams

This study was aimed at enhancing our understanding of the differences between co-located and distributed teams. We have proposed a set of hypothesis on the use of collaborative technologies, knowledge sharing processes, and performance. We conducted a quasi-experiment in IBM and collected both quantitative and qualitative data in order to compare the performance of a distributed team working around the clock as a knowledge factory with the performance of a traditional co-located team. The two teams we studied were composed of the same number of individuals, were provided with the same technologies, were engaged in similar tasks, and were given similar deadlines.

We found support for 8 of the 11 hypotheses we formulated. Specifically, as regard to technology use, while both team members relied heavily on written communication for group discussion and engaged in written discussions of similar length (disconfirming HP 1 and HP 3), we found that the distributed team sent a smaller number of broadcast style email messages and fewer logistical messages than the collocated team (supporting HP 2 and HP 4). In other words, while email messages were deemed to be essential in both cases, they were interpreted as a mechanism to share broad information by distributed team members, versus as a continuation of their informal interactions by co-located team members.

Moreover, the distributed team made greater use of documentation processes for knowledge sharing. Specifically, distributed team members used the formal source codification process to share knowledge and resolve issues prior to the feature freeze date (HP 5), and relied on formal systems for knowledge capture (HP 9). On the other hand, co-located teams relied heavily on informal face to face interactions to share knowledge, and tended not to document decision making processes. This may also explain why, on average, more than one person worked on each code element; in other words, the sociotechnical system of the co-located team was more interconnected (HP 6).

The scope of meetings varied greatly across the two teams. The distributed teams used meetings for short term issues and to assign tasks (HP 7 and HP 8). On the other hand, the co-located team conducted strategic meetings, more similar to brainstorming sessions, to discuss the status of the overall coding process and the future directions to take. Co-located team members had the opportunity to discuss short term issues and task assignments informally face to face and did not need to document such decisions.

The strategies followed by the two teams to share information and knowledge resemble the two knowledge management strategies described by Hansen et. al. (1999): a codification strategy for the globally distributed team, based on documented decisions and a personalization strategy for the co-located team, based on informal communication (see figure 2). Differently from the knowledge sharing strategies of Hansen et. al. (1999), which are planned by top management and need to reflect the overall strategy of the firm in order to be successful, the strategies for knowledge sharing and technology use that we have just described were emergent and triggered by geographical and temporal distribution. Further, the difference in knowledge sharing strategies does not depend on the *availability* of a certain technology, but on the actual use and interpretation of that technology (Orlikowski, 2000).

Haas and Hansen (2005, 2007), in their productivity perspective on knowledge sharing, pointed out that different ways of sharing knowledge bring about different outcomes. Our qualitative data support this perspective and operationalize it for a different context (distributed versus co-located teams). Specifically, while documented decisions are associated with the possibility of retaining history and re-using knowledge in a timely fashion, informal communication is associated with creativity (see figure 2).

Our data also show that there is not a statistically significant difference in the overall efficiency and quality across the two teams (HP 10 and HP 11). As far as quality is concerned, previous literature on distributed teams has already shown that distributed teams members that are together over time attain the same level of quality outcomes as that of their co-located counterparts (e.g., Dennis and Garfield, 2003). On the contrary, as far as efficiency is concerned, preliminary evidence on distributed versus co-located teams seems to suggest that co-located teams outperform distributed teams, especially for distributed teams in extreme situations, such as those characterized by a high time and space separation (e.g., Powell et al., 2004). Our evidence, instead, shows that both teams attained the same efficiency level.

A possible explanation for the similarity of performance can be found in Figure 2. Our qualitative data show that distributed team members did not strictly adhere to a pure codification strategy, but grafted elements of personalization through the introduction of a face to face meeting and informal phone calls. Such elements improved their ability to develop new and creative solutions. At the same time, co-located team members grafted seeds of codification into their personalization strategy with scheduled documentation times and the use of automated documentation tools. Such grafted strategies seem to level off team performance.

INSERT FIGURE 2 ABOUT HERE

Managerial Implications

This study supports the contention that offshore decentralization of knowledge intensive work, such as software or information systems development, can succeed with proper design and management of the dispersed team, and use of appropriate collaborative technologies. The collaborative systems can facilitate effective group interaction while preserving some advantages enjoyed by “nominal” groups of individual team members working independently.

This study also shows that the geographic structure of a team (co-located or globally distributed) does not predetermine team outcomes. Neither structure is inherently superior; both are workable models with proper adaptations. The results also indicate that geographic distribution can be leveraged by taking advantage of the possibility of continuous engagement on tasks across time zones.

At the outset, we referred to the 24-hour knowledge factory model as the evolving model for leveraging geographic and temporal differences. Over time, this notion being applied to applications of greater sophistication and with less inherent structure, by placing greater reliance on technologies to provide the necessary collaboration for handling the semi-structured work. Two kinds of environments are especially relevant to the information systems community. One is the design, development, and implementation of information systems in a manner that leverages the distributed workforce paradigm; this is already happening. The other is the development of new information system approaches that will enable this paradigm to be applied to a broad range of white-collar activities ranging from medical services to logistics planning, and from financial analysis to product design; this is where the greater challenge and opportunity lie. While we considered the scenario of distributed and sequential software development, the same principles could be applied to perform distributed product design and development work (as General Motors is doing), to create new marketing plans, to analyze data from accounting and auditing perspectives, to mine information from customers, and to conduct long-term research in medicine, biotechnology, and other fields. The challenge in each of these areas lies in being able to take traditional tasks and decompose them into a series of components, just as what happens in the case of large IT endeavors. This "commodity-based" approach allows different performs to perform the mini-tasks. Further, when tasks are modular in nature, natural breaks can serve as good hand-off points.

From a managerial perspective, the concept of 24-Hour Knowledge Factory raises several new issues. Should the work be performed exclusively on a peer-to-peer basis, or should the manager get involved? Should the pay for the workers in the different countries e the same as they are performing very similar functions, or should it be different to reflect the dissimilar cost-of-living statistics in the respective geographic settings? Should the manager be accessible around the clock in case of emergencies, or should the management function itself be transformed to a set of three managers, for each work in shifts of 8-hours? If the latter concept is accepted, how far up in the organizational hierarchy should this concept go? As an extreme case, should it apply to the corporate CEO too? Many of these emerging managerial challenges are currently being handled on a case-by-case basis, based on the type of the organization, the type of the professional work involved, and the specific choice of the three locations.

Limitations and future research directions

This research is characterized by several limitations. First, it was conducted in a single organization and with a limited number of respondents. Even though our evidence may not be generalized to other settings, the access that we were able to gain in this context enabled us to collect quantitative and qualitative evidence and to create and analyze a detailed picture of technology use and knowledge sharing processes in co-located and distributed teams. In addition, the subjects we studied are software professionals, who are similar, for many aspects of their work, to workers in many types of IT knowledge-based industries.

Second, we acknowledge that several of the problems and overheads for the distributed team occur because there of the need for frequent handoffs between people. If the individuals were not in distributed locations, but still had the same number of handoffs, we suspect that many of the same characteristics would have been observed. However, the distributed team is the primary instance where knowledge-based work will involve repeated handoffs and thus was chosen to be one of the key foundations of our quasi-experiment.

Third, we only investigated processes related to technology use and internal knowledge sharing, and did not investigate other social processes, such as external knowledge sharing, sub-group dynamics, conflict, and trust. We do not know how these emerging processes may influence the experimental results. For instance, as far as subgroup dynamics are concerned, we noticed that the subgroup members in India sat next to each other, and would often discuss items but did not have a formal meeting. This in itself is an interesting fact, which likely did have some effect on the team's functioning. However that was not studied as part of this project.

Future research directions can be framed in light of these limitations. Future studies could compare distributed and co-located teams in other settings and explore if the model we propose in figure 2 still holds; further, the model could be expanded to incorporate other social processes.

For example, the study of Cummings (2004) focused on external knowledge sharing as opposed to intra-team knowledge sharing and linked structural diversity to a higher degree of external knowledge sharing. Our study focused primarily on internal knowledge sharing, but reached a similar conclusion that having structural diversity does lead to a change in knowledge sharing practices and knowledge reuse. An extension to the present study could involve the distinction between internal and external knowledge sharing.

CONCLUSION

This paper analyzed the potential characteristics of the 24-hour knowledge factory that utilizes multiple collaborating centers located at carefully selected time-zones that are operational during daytimes in their respective countries. The efficacy of such a work environment was evaluated by creating a set of 11 hypotheses that were tested in a controlled field experiment involving one co-located team and one distributed team, characterized by similar composition, tasks, and collaborative technologies. The results show that the two teams differed in their use of technologies and in knowledge sharing processes, but not in efficiency and quality of outcomes. The co-located team and distributed team enacted a codification strategy and a personalization strategy, respectively; in each case, they grafted elements of the other strategy in order to attain both knowledge re-use and creativity.

This work contributed to the literature on knowledge sharing in distributed teams, expanding the framework of Haas and Hansen (2005) that was previously developed at the organizational level. Moreover, it offered a unique comparison of a co-localized team and a globally distributed team in a real setting. To the best of our knowledge, no previous studies have presented quasi-experiments with these aims and characteristics. We also attempted to contribute to managerial practice, by offering suggestions to managers and organizations that are interested in developing and deploying the 24 hours knowledge factory model and taking greater advantage of a globally distributed knowledge workforce. Our results suggest that the introduction of spatial and temporal separations between workers implies a corresponding introduction of new challenges; these can be overcome – and even leveraged – for strategic advantage.

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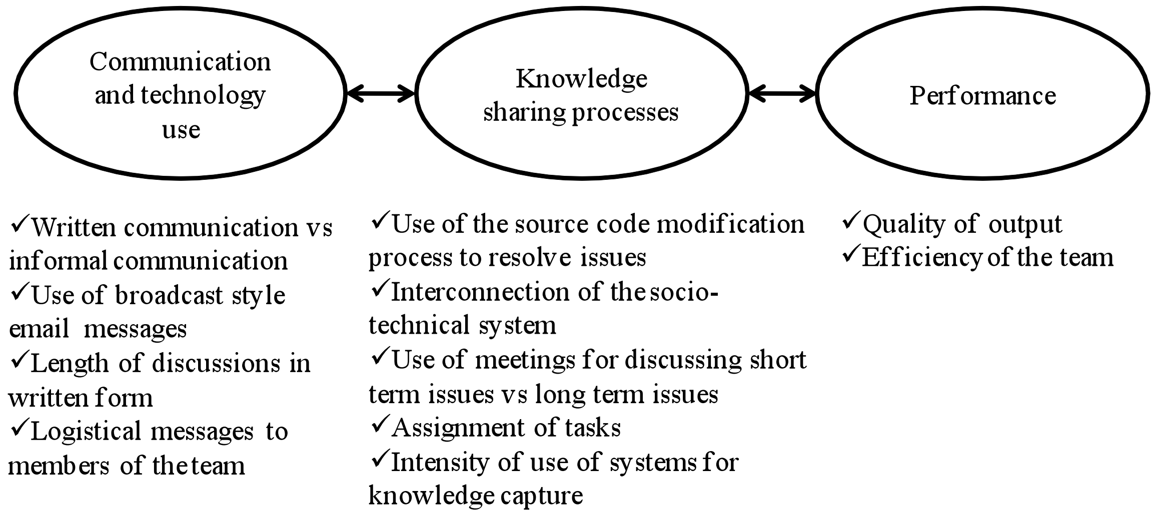

Fig. 1. A framework for technology use, knowledge sharing, and team performance

Table 1
Comparison of Outcomes for Key Process Variables

Hypothesis	Process Variable	Distributed Team		Collocated Team		t	df	t-test ($p<0.05$)
		Mean	SD	Mean	SD			
HP 1: The distributed team will rely more heavily, than the co-located team, on written communication for team discussion.	Contributors per email thread	1.73	1.55	1.50	0.74	0.94	12	Inconclusive
HP 2: The distributed team will rely less, than the co-located team, on broadcast style email messages.	Average weekly email threads	10.42	5.05	19.85	10.75	-5.56	12	Confirmed
HP 3: The distributed team will conduct longer discussions, than the co-located team, primarily in written (email) form.	Average emails per thread	2.32	2.25	1.75	0.95	1.63	12	Inconclusive
HP 4: The distributed team will send fewer logistical messages, than the co-located team, to members of the group.	Average logistical weekly emails	17.06	10.13	29.91	19.55	-4.09	12	Confirmed
HP 5: The distributed team, as compared with the co-located team, will make greater use of the source code modification process to resolve issues, in place of informal collaboration, before the 'feature freeze' date.	Source code check-ins prior to deadline	53.82	74.56	11.56	11.0	3.93	12	Confirmed

HP 6: The socio-technical system of the distributed team will be less interconnected as compared to the co-located team.	Average number of developers per code element	1.10	0.2	1.63	1.04	-3.50	12	Confirmed
HP 7: The distributed team will rely more, than the co-located team, on meetings for handling short term issues.	Fraction of tactical (vs. strategic) meeting items	0.81	0.17	0.39	0.22	10.57	12	Confirmed
HP 8: The distributed team is more likely than the co-located team to formally assign tasks to team members in meeting format.	Percent of task assignment (versus status) meeting agenda items	0.35	0.13	0.24	0.17	3.60	12	Confirmed
HP 9: The distributed team will rely more on formal systems for knowledge capture, as compared to the co-located team.	Average # of individuals modifying SPR state	3.25	0.97	1.74	0.34	10.28	12	Confirmed
HP 10: The output of the distributed team will be similar, in terms of quality, as that of the co-located team.	Average SPR actions per week	134.21	168.3	104.37	152.39	0.92	12	Confirmed
HP 11: The efficiency of the distributed team will be lower than that of the co-located team	Average SPR time to resolution	113.80	83.17	120.72	130.45	-0.31	12	Inconclusive

Table 2
The Major Advantages of Each Type of Team Mentioned by Informants during Interviews

	Distributed Team	**Co-located Team**
Use of collaborative technologies	Exploiting technology for collaboration	Using technologies as an addition to informal, face to face, interactions
Processes and interactions	Structured use of formal processes	Incidental interaction that leads to efficiency
Meetings	Meetings focused on role and tasks definition	Meetings focused on strategic discussion
Knowledge sharing	Formal logging of knowledge	Issues resolved informally, in a timely manner

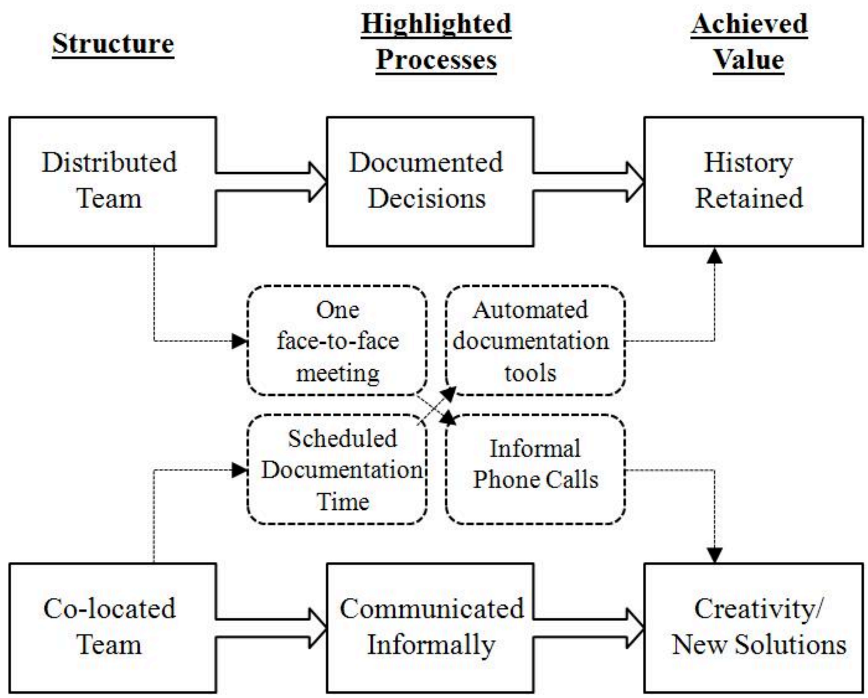

Fig. 2. A productivity perspective on knowledge sharing in globally distributed teams: a field model