Information Technology and Knowledge in Software Development Teams: The Role of Project Uncertainty

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Abstract:

Knowledge is a strategic resource; information technology (IT) is presumed to facilitate its movement among organizational members. The relevant literature, however, is inconclusive. This study reports the results of the effect of IT on knowledge-sharing processes, i.e., knowledge exchange and knowledge combination, under conditions of project uncertainty. Our results indicate that both exchange and combination are necessary to fully explain the relationships and that the consideration of a project's outcome is also important. While project uncertainty confounds the knowledge-sharing processes regardless of technology, the frequency of technology use routinely increases knowledge exchange and combination in a software team.

Keywords: Knowledge management | Knowledge sharing | Knowledge exchange | Knowledge combination | Social capital | Integrative information technology | Interactive information technology | Requirements uncertainty | Outcome uncertainty | Project uncertainty

Article:

1. Introduction

Although organizations have engaged in the creation, accumulation, and application of knowledge for many years [50], there has been an inconsistent application of knowledge as a strategic resource [31], [14]. Defined as a fluid mix of framed experience, values, contextual information, and expert insight [23], knowledge underlies organizations' products and services. To remain competitive, organizations must find better ways to manage their knowledge resources [78]. However, knowledge typically exists in specialized pockets scattered across the organization and becomes a valuable corporate asset only if it is readily available for the task at hand [23], [57]. Teams are one mechanism that can be used to bring together individually held knowledge, expertise, and skills to bear on tasks of varied nature [35].

A team is typically embedded in a larger social system such as a business unit or organization. Cohen and Bailey [18] identify four types of teams in organizations: (1) work teams, (2) parallel teams, (3) project teams, and (4) management teams. This research focuses on project teams.

Project teams differ from other teams in the non-repetitive nature of their tasks [18]. Although knowledge and expertise are important in other types of teams, knowledge sharing is key to the development of new outcomes characteristic of project teams. Project teams are generally composed of members from different functional areas that come together to share their knowledge to achieve project outcomes. Typically, project teams also search for and retrieve additional knowledge from outside the team to be integrated with their existing knowledge.

The effectiveness of knowledge sharing in project teams is often determined by the social actions among the relevant human entities inside and outside the teams [53]. These social actions are captured in the concept of *social capital* that consists of three basic dimensions: (1) a structural dimension (linkages among people or units), (2) a relational dimension (trust through interpersonal relationships), and (3) a cognitive dimension (shared understandings and interpretations) [53]. In this study, we focus primarily on the *structural dimension*, although the other two dimensions are also considered. A fundamental feature of the structural dimension of social capital is the promotion of access to other knowledge sources through a connectivity capability provided to network members [54]. This feature consequently implies a role for information technology (IT) [69].

There is scant empirical evidence of a positive relationship between IT and knowledge sharing. Additionally, the frequent failures of IT-based knowledge management systems (KMS) have been cited in the business and academic literature [12], [17]. Thus, additional research is needed to examine the role of IT in facilitating knowledge sharing, which leads to our first research question:

(1) Does IT use intensity facilitate knowledge sharing in software project teams?

Knowledge sharing results in the development of social knowledge of a team or organization [53]. The development of social knowledge comes from two very different processes: knowledge exchange and knowledge combination. Knowledge exchange requires moving various knowledge elements among human and other entities. Previous work on this concept has shown that knowledge transfer plays a critical role in the effectiveness of organizations [7], [8]. Knowledge combination is the process of blending and synthesizing separate knowledge elements or discovering new ways to mix and match elements to create new knowledge [42]. The potential of IT to facilitate and improve knowledge exchange and knowledge combination is often viewed as very high [69]. However, theory and research have yet to address how IT affects these two processes. Thus, a logical question to ask is:

(2) Does IT use intensity affect one process of knowledge sharing more than another in software project teams?

As in many studies, environmental conditions can moderate the relationship between the primary variables of interest. Project uncertainty is a prominent environmental condition that affects nearly all aspects of a software project [55], [9]. In software development teams, uncertainty in project requirements or outcomes can confound the team's ability to progress through the project. Often, the presence of uncertainty requires increases in knowledge search and retrieval and project coordination [56]. This leads to the third research question:

(3) Does project uncertainty moderate the relationship between IT use intensity and knowledge sharing?

This study uses a survey methodology to investigate these research questions. This method is an appropriate means of assessing unobservable phenomena [70], [27] such as individuals' perceptions of the characteristics of knowledge management. Additionally, a survey methodology is appropriate because the objective of the study is to empirically test the research model, which was developed based on a prior body of research that had adopted observational, qualitative, and experimental methods to examine knowledge management issues in software development teams and other organizational units [64], [81].

The remainder of the paper is organized as follows. In the next section, we discuss the theoretical underpinnings of our key constructs and propose testable hypotheses. In Section 3, we discuss the research methodology. In Section 4, we present the data analysis and results. In Section 5, we discuss the theoretical contributions and implications of our findings and the limitations of the study. In Section 6, we summarize our conclusions.

2. Theoretical considerations

2.1. Social capital

Social capital is a term that evolved from community studies centering on the importance of the networks of strong personal relationships, cooperation, and trust in everyday communities. The term was explicitly defined by Nahapiet and Ghoshal [53], who note that the central proposition of social capital theory is "that the relationships constitute a valuable resource for the conduct of social affairs, providing their members with capital, or 'credential,' that is embedded within networks of mutual acquaintance and recognition" (p. 243). An important distinction of the definition of social capital provided earlier in this paper is the view that social capital is both "a network and the assets that are moved through the network" ([53], p. 243). The inclusion of the network in this view of social capital is key to our study.

Nahapiet and Ghoshal [53] divide social capital into three different dimensions: (1) the structural dimension, (2) the relational dimension, and (3) the cognitive dimension. The *structural dimension* is composed of the "impersonal configuration of linkages between people or units" ([53], p. 244). A characteristic of this dimension that is important to the current study is the degree of interaction of the people and units in the network. IT provides support for the development, maintenance, sharing of information, and support of these networks. These characteristics are operationalized through the frequency of IT use in this study [38].

The *relational dimension* is related to the trust from the interpersonal relationships that have been developed over time through a history of interactions among network members [53]. Finally, the *cognitive dimension* encompasses understandings and interpretations that are shared by network members [53]. According to van den Hooff and Huysman [84], social capital can affect knowledge by creating access to knowledge, mutual trust among participants, and common abilities that facilitate understanding. Aspects of both relational and cognitive dimensions have been shown to relate to knowledge sharing [15].

2.2. Social knowledge

Social knowledge, as opposed to individual knowledge, represents the shared knowledge of the members of a team or an organization [15]. Social knowledge can be either explicit or tacit. Explicit knowledge is knowledge that can be objectively coded. Many organizations have moved aggressively to code, store, share, and leverage this type of knowledge using different resources, including IT [41]. Social tacit knowledge is more abstract, and it is revealed in the forms of the social and institutional practices and collective routines of an organization. This type of knowledge is not obvious to the casual observer. Social tacit knowledge is typically manifested through the sustained interaction of closely knit organizational groups [53]. Spender [77] states, "Collective knowledge is the most secure and strategically significant type of organizational knowledge" (p. 52). It is this social knowledge that is the focus of this study.

Social knowledge, such as all organizational resources, is primarily created through two different processes: exchange and combination [53]. Combination spawns social knowledge either by bringing together previously unconnected elements or by creating new and different ways of mixing elements that have been related before. In addition, there must be a process of exchange to bring together the various elements to create new knowledge.

Given the knowledge-intensive nature of software development, knowledge exchange and combination are critical to project success. Combination is fundamental to software development because teams combine individual perspectives to develop shared project concepts. Additionally, teams synthesize their members' expertise and know-how to jointly solve project-related problems [85]. Prior studies have also reported that IT teams improve their task efficiency by sharing their knowledge internally [82].

It has been acknowledged by prior studies that knowledge exchange is critical to timely project completion [50]. Exchange can originate either from repositories holding the explicit knowledge or between organizational members [53]. Studies in the new product development literature suggest that teams with more external communication perform better than teams with a low frequency of external communication [4], [5]. Teams have also been found to improve their operational efficiency by acquiring knowledge from external sources [88].

Despite their importance, knowledge exchange and knowledge combination have been seldom examined in software teams. Additionally, the literature offers no testable model to explain if IT impacts these processes similarly or differently.

2.3. Information technology and knowledge combination and exchange

Moran and Ghoshal [51] provide three necessary conditions for the enhancement of the knowledge sharing of resources. The first condition, which is associated with IT, is that it provides an increased opportunity to share knowledge. Simply put, access to knowledge resources seems to be enhanced with IT. Socially based KMSs and intranets provide greater access to knowledge bases and to knowledgeable individuals who can share their expertise in solving organizational problems.

The second condition is that an anticipation of knowledge sharing will result in increased value; in this case, value is manifested in knowledge creation. It is reasonable to assume that IT has the capacity to increase network ties through increased communication capabilities. Stronger network ties facilitate the belief that knowledge sharing will prove worthwhile [53]. The third condition is the importance of motivation. It asserts that organizational members must be willing to interact with the system in anticipation of receiving a benefit of some sort. Nahapiet and Ghoshal [53] added a fourth condition, combination capability, which is very similar to absorptive capacity [19].

The above discussion points to the role of IT in affecting at least two of the conditions necessary for knowledge sharing, most noticeably the opportunity for exchange and combination. The potential of IT to facilitate and improve knowledge exchange and knowledge combination is often viewed as very high [69]. For the purpose of this study, IT applications that facilitate these two processes are presented in two broad classes: integrative and interactive [87].

Zack [87] notes that integrative applications assist “a sequential flow of explicit knowledge into and out of a repository” and that in such applications, “the repository becomes the primary medium for (explicit) knowledge exchange, providing a place for members of a knowledge community to contribute their knowledge and views” (p. 50).

Interactive applications “focus primarily on supporting interaction among those people with tacit knowledge” ([87], p. 51). The IT in this category may also be called collaborative technology and includes such applications as chat, instant messaging, video and audio conferencing, and group decision support systems. Such applications can support one-on-one communication or enable communications among a group of individuals.

In this study, we examine the impact of both integrative and interactive IT applications on knowledge exchange and knowledge combination in software teams. Because general purpose IT applications used for routine work such as software coding or debugging are not a part of integrative or interactive technologies, they are not included in this study.

2.3.1. Knowledge exchange

Many advanced tools now exist that allow for the rapid discovery and exchange of knowledge. Search and retrieval technologies allow ad-hoc queries on knowledge sources such as bulletin boards, discussion group forums, blogs, wikis, and directories. Many of these knowledge sources also allow for proactive actions in acquiring knowledge by asking questions on group forums. More formal IT systems such as Lotus Notes and other KMSs also enhance knowledge exchange in organizations [61].

IT can also facilitate knowledge exchange in a way other than directly providing the knowledge itself. Interactive technologies can help team members obtain knowledge inputs from external experts. IT can also be used to identify and locate individuals with specialized expertise regardless of that individual's physical location. Additionally, IT can fulfill a team's demands for coordination with their peer teams and with other project stakeholders [44].
Mitchell [50] examined enterprise application integration projects and found that coordinative activities are evident in projects that are completed in a more timely manner.

However, research has indicated that the mere presence of IT is not sufficient to facilitate knowledge exchange [69]. Extant literature that examines knowledge exchange and IT has not consistently found a relationship [54], [68]. Huber [37] reported that to be effective, KMSs demand a high level of use and participation. Senders or contributors might be reluctant to share their knowledge because of a fear of being taken advantage of or losing power. Receivers may not utilize IT to access outside knowledge sources because of the “not-invented-here” syndrome [37]. Still, in many cases, as receivers and senders increasingly utilize IT, they become increasingly comfortable with its use and begin to mold it into a form that is acceptable to them [61]. In this way, trust in the system is built over a period of time. Slaughter and Kirsch [75] confirmed this proposition in their study examining the effectiveness of knowledge exchange mechanisms. They found that the frequency of the use of knowledge-exchange mechanisms is related to the effectiveness of tacit knowledge exchange. Taking all of this into consideration, the following hypothesis is offered:

H1a. There is a positive relationship between IT use intensity and knowledge exchange.

2.3.2. Knowledge combination

Knowledge combination is associated with the synthesis of individuals’ specialized knowledge into systemic-level contextual knowledge [2]. Within a specific context, knowledge combination allows for the establishment of a larger base of relevant and targeted knowledge to solve the organizational problem or task at hand.

Teams provide a mechanism for knowledge combination [60], and software teams routinely combine individual expertise when working on projects. Alavi and Tiwana [2] proposed that interactive technology could benefit knowledge combination by facilitating the process of synthesizing individual knowledge into task-specific knowledge. Interactive technology also seems ideal to facilitate the specific processes, rich communication, collaboration, and creative conflict that are key to knowledge combination in teams. This is especially true in software development teams, as they frequently struggle with projects characterized by complex technologies and software architectures, ambiguous project requirements, and unpredictable outcomes [43]. Prior studies have found that group members using interactive technology generate more ideas than when working face-to-face (Straus and McGrath, 1994).

Collaborative systems may be particularly effective in promoting communication among team members, thus creating a shared understanding of project-related issues [71]. A team's usage of collaborative systems may improve its internal climate, making the environment conducive to combining individual knowledge and skills. These arguments lead to the next hypothesis:

> **H1b.** There is a positive relationship between IT use intensity and knowledge combination.

2.4. Relational capital and knowledge combination and exchange

Relational capital is characterized by mutual trust, strong personal relationships, and reciprocal behavior [40]. Much of the previous research in this area has focused heavily on trust [16]; trust has been shown to influence knowledge sharing [84]. In the context of teams, trust is defined as the "degree of confidence of team members in one another" ([63], p. 145). Trust may impact knowledge sharing in a multitude of ways. First, trust removes the suspicion of opportunistic behavior among team members [11]. This enables individual team members to freely share knowledge that is critical to the project [67]. Second, a team that is high in trust has more confidence among its members that everyone will meet their knowledge commitments toward each other and toward the team goals. This facilitates knowledge combination by increasing the variety of information that team members are willing to share [6]. Third, trust promotes harmony and reduces interpersonal tensions, which enable both knowledge combination and exchange [24].

In addition to trust, high levels of relational capital also signify strong interpersonal relationships and reciprocal behavior [15]. Team members sharing strong interpersonal relationships are expected to freely exchange their knowledge with each other. Strong interpersonal relationships among team members may also influence their readiness to accept each other's diverse knowledge inputs and to synthesize them to solve project-related problems [81]. Reciprocal behavior may also contribute to knowledge exchange because members may be more likely to share their uniquely held knowledge with each other. Finally, if the required knowledge is not available within the team, both strong interpersonal relationships and reciprocal behavior may motivate team members to source the required knowledge from their external contacts or from other knowledge sources. To summarize, a high level of relational capital in a software team is expected to reinforce the team's efforts to effectively exchange its knowledge resources and to combine them innovatively to accomplish project goals. Therefore, we propose:

> **H2a.** There is a positive relationship between relational capital and knowledge exchange.

> **H2b.** There is a positive relationship between relational capital and knowledge combination.

2.5. Team cognition, knowledge combination and knowledge exchange

Team cognition is concerned with homogeneity of the team, i.e., the extent to which the team members are similar to or different from each other. While homogeneity is important in order to reach consensus, we believe that it may detract teams from innovative solutions that are critical to some software development projects. Thus, heterogeneity may be more important to the combination and exchange processes.

Heterogeneous teams have members with diverse technical and functional backgrounds, and they may have extensive interpersonal networks in their respective domains that they can utilize as sources of external knowledge [76]. Furthermore, compared to homogenous teams, heterogeneous teams also have experts in multiple domains, and experts compared to novices have more elaborate schema of how to apply their knowledge to remove inconsistencies [81]. Homogenous teams, which typically have experts in the same domain, will have a lesser capacity to apply knowledge in multiple domains compared to heterogeneous teams [3]. Therefore, homogeneous teams, compared to heterogeneous teams, may not only have limited access to diverse external knowledge sources but also have a lesser capacity to exchange knowledge inputs in those domains. Hence, homogeneity is likely to have a negative effect on a team's knowledge exchange.

H3a. There is a negative relationship between team cognition and knowledge exchange.

A team's knowledge heterogeneity fulfills a fundamental pre-condition for its knowledge integration: the presence of differing knowledge among team members [21]. Team members are likely to expect that others do not possess the unique knowledge they do and that everyone needs to contribute their distinctive knowledge to accomplish their project goals [45]. On the other hand, given the team's uniform knowledge distribution, members of homogenous teams may lack such expectations and thus lack the desire to contribute to a team's knowledge pool.

This could be more problematic for homogeneous teams than it sounds. First, they may have to spend extra effort to motivate their members to apply their skills and abilities to the project. Second, in the absence of much technical and functional diversity, members may have to rely on themselves to integrate knowledge inputs from other domains [45].

Compared to homogenous teams, teams with technical and functional diversity are compelled to create a common understanding among team members. Once the common understanding is reached, heterogeneous teams can integrate diverse member skills and abilities more actively than can homogenous teams, which lack technical or functional diversity. Homogeneous teams may also be constrained in their ability to conceptualize and execute novel project-related ideas [34], [33]. Thus, we posit:

H3b. There is a negative relationship between team cognition and knowledge combination.

2.6. The role of project uncertainty

Project uncertainty is a cross-discipline issue that is commonly addressed in the literature (e.g., [46], [62], [86]). While project uncertainty is a common situation in many different types of projects, it is particularly apparent in complex tasks such as software development [39].

Software development is a knowledge-intensive activity, and uncertainty in software projects refers to the lack of critical knowledge pertaining to project-related areas [89]. Previous studies have identified project requirements and project outcomes as key areas in which knowledge scarcity escalates project uncertainty [55], [56], [48]. Based on the above discussion, uncertainty in software projects is broadly defined as an inadequacy of requirement-related knowledge that reduces the team's ability to predict project outcomes, which in turn increases the need for the exchange and combination processes. For example, if a project meets with unexpected problems (e.g., a previously undefined process), the requirements and outcomes will both need to be modified, thus creating uncertainty. This uncertainty is the result of unavailable or low-quality information [47], and exchanging knowledge reduces this uncertainty by increasing the amount and quality of information [9].

Simply finding the information (e.g., knowledge exchange) is not always enough to reduce uncertainty, however. When project uncertainty increases, additional information must be exchanged within the team and from external sources. Then, to make sense of the new information, the team must arrive at a shared interpretation of the information [9]. The process of arriving at a shared interpretation requires that the team be able to combine their expertise and understanding to facilitate the application of information that is specific to the needs of the project. This knowledge combination process is of particular importance in project teams, where the source of uncertainty is novelty [47]. This leads to the next two hypotheses:

> **H4a.** There is a positive relationship between the level of project uncertainty and knowledge exchange.
>
> **H4b.** There is a positive relationship between the level of project uncertainty and knowledge combination.

As project uncertainty increases, mechanisms to exchange and combine information are also expected to increase. Research suggests that the more novel the problem (e.g., new technology), the more difficult the exchange of asymmetrical knowledge becomes [28]. It therefore becomes necessary to not only gather information to reduce uncertainty but to also ensure that a variety of information sources are sought to gain the greatest insights into the problem and to reduce the potential for collecting false or misleading information. This knowledge may reside in information repositories where search and retrieval technologies are needed, or it may be held by external experts and other knowledgeable personnel. In these cases, team members are likely to make even greater use of integrative technologies for search and retrieval and interactive technologies to communicate with knowledgeable personnel and to bring the necessary knowledge into the project to alleviate a heightened uncertainty condition.

Once information has been exchanged, it then becomes necessary to begin the process of combining the new information with extant information so that new knowledge is derived. Asymmetrical knowledge will exist until sufficient interaction between team members allows each team member to have a similar understanding of the issues at hand. The use of interactive technologies to facilitate this knowledge combination is expected to be greater because of the frequent discussions and interactions within the project to apply the new knowledge effectively. The interpersonal networks of the team members that are employed to more effectively apply knowledge are utilized more frequently as uncertainty increases [44]. The importance and utilization of interactive technologies is again likely to increase as the use of these interpersonal networks increases. These arguments lead to the following hypotheses:

> **H5a.** Project uncertainty positively moderates the relationship between IT use intensity and knowledge exchange.

> **H5b.** Project uncertainty positively moderates the relationship between IT use intensity and knowledge combination.

As discussed previously, there is a difference between knowledge exchange and knowledge combination. Exchange focuses on gathering data for use in the combination process, whereas combination focuses primarily on the interactive communication between team members. Because exchange is well facilitated by IT, we expect that it will have a stronger direct effect on the exchange process than on the combination process. Conversely, because combination is a traditionally more communicative process, we expect that the more socially oriented constructs of relational capital and team cognition will have a greater impact on the combination process than on the exchange process. Therefore, we posit that:

> **H6a.** IT use intensity will have a stronger impact on knowledge exchange than on knowledge combination.

> **H6b.** Relational capital will have a stronger impact on knowledge combination than on knowledge exchange.

> **H6c.** Team cognition will have a stronger impact on knowledge combination than on knowledge exchange.

2.7. Most successful projects vs. least successful projects

Knowledge and knowledge management have been cited as critical issues in order for organizations and projects to gain higher performance [50], [54]. It is widely believed that teams or organizations that more effectively create and manage their knowledge resources will perform better, all other things being equal [36]. This belief is supported by the number of practitioners who have initiated and implemented knowledge management programs in their companies [36]. Additionally, the amount of attention that knowledge management has received in the academic press provides evidence of the perceived value of this resource in organizations [1].

Looking at it another way, it might also be expected that organizations or projects that perform better might also have better knowledge management processes, all other things being equal. Additionally, the antecedents of the knowledge exchange and combination processes would logically have greater effects on these higher performing organizations or projects. For example, higher performing teams are likely to make use of the expertise in their network to reduce uncertainty and develop innovative solutions. These teams are also more likely to draw on relational capital to trust interactions with various sources and find ways to reduce the effects of uncertainty. Much of this would require an increase in the use of communicative technologies. Therefore, even though it has been argued that IT will have positive effects on both knowledge exchange and knowledge combination, these effects will likely be greater in projects that are more successful because higher performing teams may have learned to use the technology to its full advantage. Thus, we expect that the relationship between IT use intensity and knowledge processes will be stronger for those projects.

However, there is little literature that investigates team performance in the context of knowledge management, social capital, and project uncertainty. Because it is logical that one or all of these processes might differ between projects of varying success, we include project success as a control variable.

3. Research methodology

This research used a survey methodology to collect data from software development teams. This method is an appropriate means of assessing unobservable phenomena [70], [27], such as individuals' perceptions of knowledge management characteristics. A survey methodology was adopted because the objective of the study was to empirically test the research model that was developed from a prior body of research [64]. A case method or observational method is more appropriate when the boundaries of the research phenomena are not clearly evident, typically because of the lack of a priori knowledge and a strong theoretical base [10]. Thus, case method and observational methods are typically adopted, either by themselves or in conjunction with a survey method, to generate a priori knowledge about the variables of interest and their measurement (see [26], p. 579). Our research model already has theoretical foundations in a previous body of research that had adopted observational, qualitative, and experimental approaches to examining knowledge management issues in software development teams and other organizational units (see [85], [88], [60], [32], [49], [73]).

We performed the survey methodology in accordance with the guidelines developed by Flynn et al. [25], who suggest that empirical research should be approached systematically. This systematic approach begins with the establishment of a foundation for the study and ends with the use of appropriate statistical techniques to derive meaningful results. This study established a foundation of social capital theory, knowledge exchange and combination, frequency of IT use, and uncertainty, and then selected a sample that reflected the current knowledge and experience in this context, employed an appropriate data gathering method, and finally used a rigorous statistical technique to study the relationships between variables [25].

3.1. Measures

Consistent with their conceptualization, the constructs were measured as the team leaders' perceptions of their respective teams. To enhance the validity of the construct measurement, scales were adapted from prior studies [79]. They are discussed below. A total of 23 items were measured using a 7-point Likert scale.

Previous studies on knowledge sharing and organizational learning contributed to the items for our first dependent variable: knowledge exchange [80], [58]. A high score on knowledge exchange indicates the team's active utilization of knowledge from external sources. The second dependent variable, knowledge combination, was measured using items from previous studies in the areas of knowledge combination and organizational learning [82]. A high score on knowledge combination indicates that the team vigorously combines and assimilates its internal knowledge resources to create systemic project-level knowledge.

For the purpose of this study, IT use intensity includes both coordinative processes (interactive technology) and search/retrieve processes (integrative technology). A high score on either scale indicates that the team routinely and frequently uses IT to coordinate projects, collaborate, or to search for and retrieve extant information. These items were adapted from previous studies on knowledge management and IT [29], [74].

Project uncertainty was operationalized in this study as requirements and outcome uncertainty. High scores on these scales indicate that the team encountered uncertainty in these areas. Questions regarding uncertainty are based on prior studies in the field [55], [83].

Relational capital items were adapted from the work of Kale et al. [40], who identified the level of mutual trust among team members, the closeness of their working relationships, and their level of reciprocal behavior as three indicators of a team's relational capital. A high score indicates that the team members share mutually trusting relationships. Team cognition was captured using items developed by Campion et al. [13]. A high score indicates that the team possesses a variety of knowledge, skills, and expertise. The control variable is project success, noted as either the most successful project the team had worked on or the least successful project the team had worked on.

3.2. Pre-test

The instrument was subjected to a conceptual validation exercise based on recommendations by Moore and Benbasat (1991). Four sets of items were printed on separate cards and were given to four IS doctoral students in an unordered fashion. The students were also provided the names and definitions of the constructs and were asked to sort the items by assigning them to various construct categories or an “other” (no fit) category. This process helped identify questions that were ambiguously worded or did not fit with other questions.

The four sorters correctly assigned 94.4 percent of the items to their intended constructs; the inter–rater reliability was 0.98. Based on the feedback from this exercise, three items were dropped, including two from the knowledge application construct and one from the IT usage frequency construct. This resulted in a final instrument with 23 items. These items are shown in Appendix A.

3.3. Data collection

Following the key informants methodology, data were collected from project leaders in nine mid- to large-size software services firms in India. Project leaders were chosen as key informants because they possessed the most comprehensive knowledge of their team processes [72]. Thus, their responses could be used to represent aggregated information about the team activities being examined [63]. The nine firms provided custom-made software solutions to Fortune 1000 clients and were chosen because of the similarity of their operations. Additionally, all the firms are Capability Maturity Model (CMM) Level 5 companies; this increases the consistency among their software development processes.

To secure a firm's participation, the chief knowledge officer (CKO) in each firm was contacted by phone or e-mail. The CKO was explained the intent of this study, and his or her cooperation in data collection was solicited.

The CKOs were contacted for two reasons. First, it was expected that the focus of this study on knowledge exchange and combination in software teams will align more with the job interests of CKOs than with other members of the top management team. Their cooperation was also cemented by promising them the summary results and final recommendations of the study. Second, all the CKOs contacted for this study were vice-president level executives, and their offices had access to various employee listservs through which they communicated with different employee groups (e.g., project team leaders, account managers, and team members) in their firms.

After obtaining the necessary approval from each firm, an e-mail containing brief details of the study, the link to the online questionnaire, and the instructions was sent to the CKOs' offices. To ensure that the respondents were project team leaders, the CKOs' offices forwarded that email only to the project leader listservs in their respective organizations. Overall, 225 project leaders were asked to participate across nine organizations.

Respondents were asked to answer the questions twice for two separate projects in which they acted as project leaders. One response was in reference to the most successful project outcome they had attained, and the second was for the least successful outcome. Each style of questionnaire (most first or least first) was alternately assigned to subsequent respondents as they entered the online survey, so half of the respondents began with the questionnaire for the most successful project and half began with the questionnaire for the least successful project. The instructions in the questionnaire further asked the respondents to answer the questions using that project as the reference source. For example, a respondent who was assigned the most successful style first was asked to think of the most successful project he or she had managed. Next, the respondent was presented with a second questionnaire that asked him or her to think of the least successful project that he or she had managed. Thus, respondents filled out two questionnaires: one for the most successful project they had managed and one for least successful project they had managed.[1] In addition, demographic-based questions were included in both questionnaires.

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[1] CMM Level 5 certification ensured that the participating firms had standardized definitions of software development processes and project outcomes, such as success [30]. For this reason, success was measured as a yes/no variable in this study.

An a priori sample size requirement analysis was performed to determine a sample size adequate to assess significance at a power level of 0.80. A Partial Least Squares (PLS) analysis is used in this study. PLS can be used to analyze structural models with multiple-item constructs (Ahuja et al., 2003; Chin and Todd, 1995) and is particularly suited to predictive applications and theory building (Gefen et al., 2000).

Of the total 225 project leaders across nine firms, 161 respondents provided responses for both least and most successful projects, for a 71.56 percent response rate. Of those responses, eleven least successful responses and twelve most successful responses were incomplete and were therefore excluded from subsequent analyses, leaving 150 least successful project responses and 149 most successful project responses for analysis. Seventy-eight percent of the respondents were male; the average industry experience for all respondents was 8.8 years. Eighty-four percent of the projects (both most and least successful) were customized software development projects, while the remaining projects were product development projects. The average project duration was 11.5 months, and the project team size averaged 15 members. Each of these demographics was tested for a potential effect; none was found, and therefore, none was included in the analyses below.

3.4. Scale validity

Prior to examining our hypotheses, the constructs were examined for reliability and validity. Reliability was analyzed using Cronbach's alpha that represents a coefficient of reliability or internal consistency. Cronbach's alpha for each construct exceeded the suggested value of 0.70 [59]. Table 1 includes descriptive statistics, Cronbach's alpha, and the composite reliability of each construct.

Table 1. Descriptives and correlations.

	#	M	SD	Skew	Cr A	1	2	3	4	5	6	7
1. Uncertainty	6	4.11	1.75	−0.27	0.86	−0.77						
2. Cognition	3	4.89	1.31	0.72	0.79	−0.09	−0.84					
3. Relational capital	3	5	1.1	0.4	0.78	−0.17**	−0.22**	−0.86				
4. Combination	4	5.31	1.22	−1.15	0.93	−0.25**	−0.31**	0.56**	−0.9			
5. Exchange	3	5.06	1.17	−0.79	0.76	−0.23**	−0.31**	0.39**	0.62**	−0.87		
6. IT Use Intensity	4	5	2	−0.66	0.95	−0.15**	−0.25**	0.17**	0.30**	0.42**	−0.94	
7. ITUI × uncertainty						−0.64**	−0.23**	0.01	0.04	0.15**	0.63**	(0.80)

** Correlation is significant at the 0.01 level.

Individual items were tested for convergent and discriminant validity using factor analysis with SmartPLS 2.0 (www.smartpls.de). The results of this analysis indicated that all items were highly correlated within their construct and no item loaded lower on its intended construct than on another, showing both convergent and discriminant validity [20] (see Table 2).

Common method bias was assessed in accordance with the recommendations of prior research [65]. The responses in this study were obtained anonymously, and the measures were not only adapted from previously established instruments but were also tested and adjusted prior to the administration of the questionnaire. Both of these procedures are useful in reducing common method bias. In addition, Table 1 shows the correlations between factors in this study; the highest correlation is $r = 0.62$ between knowledge exchange and knowledge combination, which is well below the threshold of $r = 0.9$ [65]. Table 2 shows the results of the confirmatory factor analysis that demonstrates that variance is distributed among the factors in this study rather than being concentrated on one factor [65]. These indicate that common method bias, if it exists, is unlikely to confound the interpretation of the results.

Table 2. Results of confirmatory factor analysis.

	Success	**Exch**	**Comb**	**IT**	**Cog**	**Unc**	**Rel**
Success	**1**	0.0847	0.1585	0.0889	−0.0672	−0.1323	0.0898
Exch1	0.0447	**0.8225**	0.4483	0.2686	−0.2427	−0.1957	0.3523
Exch2	0.0867	**0.7461**	0.4034	0.3476	−0.2137	−0.1939	0.2595
Exch3	0.0771	**0.8889**	0.4918	0.402	−0.3115	−0.2102	0.3967
Comb1	0.1362	0.5846	**0.9046**	0.2236	−0.2835	−0.2492	0.5106
Comb2	0.139	0.5704	**0.9125**	0.3177	−0.3465	−0.2619	0.4982
Comb3	0.1658	0.5351	**0.8947**	0.2327	−0.2733	−0.2228	0.5517
Comb4	0.1324	0.5969	**0.9058**	0.3263	−0.2429	−0.2668	0.5554
ITUI1	0.0657	0.4015	0.2604	**0.9202**	−0.2507	−0.1196	0.1413
ITUI2	0.086	0.3684	0.2537	**0.9416**	−0.2708	−0.0654	0.1448
ITUI3	0.1127	0.4165	0.3171	**0.9356**	−0.1919	−0.1672	0.2272
ITUI4	0.066	0.372	0.3073	**0.9484**	−0.2273	−0.1588	0.2103
Cog1	−0.0491	−0.2827	−0.2631	−0.2497	**0.844**	−0.1082	−0.1795
Cog2	−0.0526	−0.2328	−0.235	−0.184	**0.8542**	−0.0763	−0.1699
Cog3	−0.0662	−0.2731	−0.2913	−0.1896	**0.815**	0.0225	−0.2066
Unc1	−0.0715	−0.2062	−0.2806	−0.1161	−0.0127	**0.8609**	−0.1927
Unc2	−0.1417	−0.2257	−0.2572	−0.0939	−0.0488	**0.8779**	−0.1705
Unc3	−0.1703	−0.2124	−0.2721	−0.0915	−0.0204	**0.8959**	−0.2001
Unc4	−0.1025	−0.1095	−0.0766	−0.1824	−0.1338	**0.5448**	−0.0917
Unc5	−0.0523	−0.2115	−0.1824	−0.1431	−0.0574	**0.7505**	−0.1535
Unc6	−0.0587	−0.099	−0.0794	−0.0617	−0.1363	**0.6106**	−0.0504
Rel1	0.0316	0.26	0.4152	0.0198	−0.1708	−0.1022	**0.8096**
Rel2	0.028	0.3212	0.3778	0.1482	−0.2221	−0.1093	**0.8196**
Rel3	0.1345	0.415	0.4057	0.2659	−0.1693	−0.2503	**0.8512**

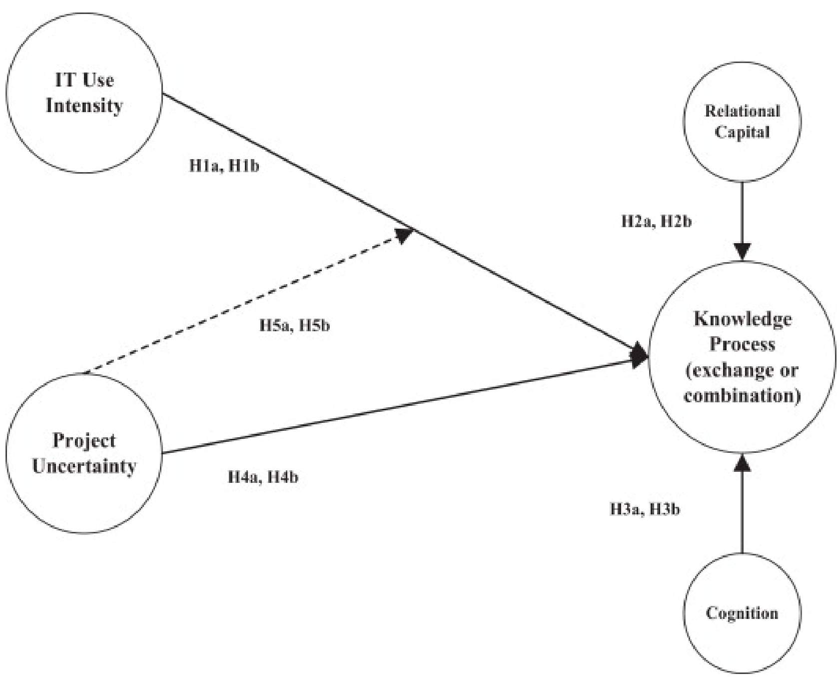

Fig. 1. Conceptual research model.

We tested for multicollinearity and found that all variance inflation factors for our predictor variables were at most 1.534, which is well below the standard cutoff of 10 [52]. Furthermore, the lowest tolerance is 0.652. Both of these statistics indicate that multicollinearity is not an issue; the conceptual model is shown in Fig. 1.

4. Data analysis and results

Table 3 summarizes the results of H1a, H1b, H2a, H2b, H3a, H3b, H4a, which focus on the main effects of the intensity of IT use, relational capital, team cognition, and project uncertainty on knowledge exchange and combination. In addition, Table 3 shows the results for the moderation Hypotheses 5a and 5b. Direct effects and moderation effects were analyzed separately for each knowledge process.

Table 3. Results of H1a, H1b, H2a, H2b, H3a, H3b, H4a, H4b, H5a.

	H1a, H2a, H3a, H4a Exchange ***β***	**H1b, H2b, H3b, H4b Combination** ***β***	**H5a Exchange** ***β***	**H5b Combination** ***β***
IT use intensity	0.291***	0.139**		
Relational capital	0.283***	0.48***		
Cognition	−0.191***	−0.18***		
Project uncertainty	−.159***	−0.165***		
Project success	0 NS	0.068*	0.002 NS	0.068*
IT × proj. unc			0.227*	0.002 NS
Adjusted R^2	0.33	0.44	0.33	0.44

* Significant at the 0.05 level.
** Significant at the 0.01 level.
*** Significant at the 0.001 level.

H1a, H1b, H2a, H2b, H3a were supported because relational capital, team cognition, and IT use intensity were significantly related to both knowledge exchange and knowledge combination. Hypotheses 4a and 4b, which posited a positive impact of project uncertainty on knowledge exchange and combination, were not supported; on the contrary, the relationships between uncertainty and knowledge exchange and knowledge combination were both negative and significant. Analyses of project uncertainty as a moderator showed that it had a significant effect on the relationship between IT use intensity and knowledge exchange, but it did not significantly affect the relationship between IT use intensity and knowledge combination. Thus, Hypothesis 5 was partially supported.

In Hypothesis 6, we had proposed that IT use intensity, relational capital, and team cognition would have differential effects on knowledge exchange and knowledge combination. Table 4 shows the results. As expected, there was a greater effect of IT use intensity on knowledge exchange than on knowledge combination and a greater effect of relational capital on knowledge combination than on knowledge exchange. However, there was no difference in the effect of team cognition on the two knowledge-sharing processes. Thus, Hypothesis 6 was partially supported.

Table 4. Results of Hypothesis 6.

Exchange vs. combination	Significance of difference *t*
IT use intensity	2.68**
Relational capital	−3.427***
Cognition	−0.2 NS

** Significant at the 0.01 level.
*** Significant at the 0.001 level.

Because we believe that these antecedents are likely to have different effects in successful projects than in non-successful projects, we included project success as a control variable in the analyses. While there was no difference between groups for knowledge exchange, there was a significant difference, although slight, in the context of knowledge combination. This same relationship held for the moderation models. Therefore, an additional analysis was performed to isolate where the differences occurred.

There was no difference between the most and least successful projects in terms of the effects of the intensity of IT use or team cognition on knowledge combination. There was a difference between the projects regarding the effect of relational capital on knowledge combination, where the most successful projects experienced a greater effect from relational capital. There was also a significant difference in the effect of project uncertainty between the two groups: project uncertainty affected knowledge combination less in the least successful projects compared to the most successful projects. There was also a significant difference in the moderation effect of project uncertainty between the two groups ($t = 6.264$). While the most successful projects intensified their use of IT as uncertainty increased, the least successful ones reduced their use of IT.

Further analysis was conducted to isolate the differences, if any, between groups in the context of knowledge exchange. There were significant differences in the effects of IT use intensity, relational capital, and team cognition on knowledge exchange. There was also a difference in the effect of uncertainty. In addition, moderation was significant for the most successful projects but not for the least successful projects. Table 5 summarizes these results.

Table 5. Results of most vs. least comparisons.

Most vs. least	Significance of difference combination *t*	Significance of difference exchange *t*
IT use intensity	−0.197 NS	2.126*
Relational capital	1.751#	−1.979*
Cognition	1.451 NS	1.987*
Uncertainty	−3.118**	−1.9#
ITUI × uncertainty	6.264***	0.9^

* Significant at the 0.05 level.
** Significant at the 0.01 level.
*** Significant at the 0.001 level.
# Significant at the 0.10 level.
^ Moderation is significant for the most but not the least successful projects.

5. Discussion

Social capital theory proposes that the resources, both actual and potential, that are created and manipulated through the network of relationships of a social unit are likely to yield value to that unit. Nahapiet and Ghoshal [53] argue that social capital facilitates the creation and sharing of knowledge. Knowledge has emerged as a primary resource that can provide a sustainable competitive advantage for firms [1]. Nahapiet and Ghoshal [53] divide social capital into three dimensions: the structural dimension, the cognitive dimension, and the relational dimension. IT seems to be a natural fit as a component of the structural dimension in its role as an access facility among parties that are in the process of establishing or strengthening relationships.

Our hypotheses began with assertions that the intensity of IT use will have a positive effect on both knowledge exchange and combination. In both cases, the hypotheses were supported. These results support the often conjectured but not well empirically supported idea that IT has a positive impact on knowledge management. These results also contribute to the social capital theory, as IT was posited as a component of the structural dimension of social capital. Furthermore, our results showed that knowledge exchange is more affected by IT use intensity than by knowledge combination. The exchange of information is easily supported by IT, particularly integrative technologies [87], [61], and most likely accounts for the difference. Although the results showed that IT can be useful in knowledge combination, the effect of IT was not as striking. This too is reasonable, as combination entails more application. Thus, team members come together to discuss plans and achieve consensus; these processes are sometimes difficult to facilitate strictly through IT [87], [61]. This result indicates that exchange and combination are distinctly different processes within the knowledge management domain, a proposition that until now has had very little empirical support.

Our next hypotheses asserted that relational capital would have a positive effect on both knowledge exchange and knowledge combination. The results indicated that relational capital had a significant effect on both exchange and combination. Relational capital allows team members to interact confidently with one another. This indicates that during the exchange process, one team member trusts that information coming into the team is appropriate even though it might come through another team member. Relational capital, however, is more critical to knowledge combination, which involves team members assimilating dissimilar ideas into a cohesive solution. Relational capital smoothens this process, particularly through an expectation of reciprocation [15]. As hypothesized, relational capital had a significantly stronger effect on knowledge combination than on knowledge exchange. This lends further support to our contention that combination and exchange are distinctly different processes.

The third set of hypotheses posited that team cognition would negatively affect both knowledge combination and exchange. The results indicated that cognition had a significant negative impact on both processes. Knowledge exchange may be affected because compared to heterogeneous teams, homogeneous teams may lack diverse interpersonal networks of external knowledge sources, which constrains the variety of knowledge inputs they can acquire externally [76]. In the absence of technical and functional diversity, the knowledge combination activities of a homogeneous team may also be compromised. This may occur because the team may lack the foundation for effective knowledge integration, i.e., the presence of differing knowledge among the team members [21].

Our fourth set of hypotheses posited that uncertainty would positively impact the two knowledge processes. Project uncertainty was significantly related to both knowledge exchange and combination, but the relationship was negative. This means that as uncertainty increases, the project team members decrease both knowledge exchange and knowledge combination. These results were certainly unexpected, but can be explained using the information-processing perspective. Based on this perspective, teams create appropriate information-processing capabilities to manage uncertainty [55]. In the face of increased uncertainty, teams limit the exchange and combination of knowledge to avoid overwhelming their information-processing capabilities [66].

A more detailed look at the internal dynamics of uncertain projects provides an additional explanation. Uncertainty is characterized by a lack of critical information inputs, and it seems that teams that face uncertainty lack key information regarding what knowledge inputs to acquire and how to integrate them into the teams' knowledge pools, which hurts their knowledge exchange as well as combination efforts [89].

The moderating effect of uncertainty on the relationship between IT use intensity and knowledge exchange was significant. It seems that as uncertainty increases, software teams increase their use of IT to support knowledge exchange. Barki et al. [9] reported that in the face of uncertainty, more information is needed, and it seems that when uncertainty increases, project team members use IT more for general environmental scanning in an attempt to discover ways to decrease this uncertainty. Tools such as Google and other search technologies can be utilized for such purposes.

5.1. Most successful vs. least successful projects

We also examined the differences between the most and least successful projects. To begin with, we found that the effects of IT use intensity were significantly greater on knowledge exchange for successful project teams. This adds to the evidence that IT use is important in knowledge exchange, maybe to the extent that this is a key factor in determining whether projects are successful or not.

Our investigation of the differences in the relationships between the most and least successful projects indicated that the positive effect of relational capital was greater on knowledge exchange in the least successful projects. It might be that team members working on these projects recognize that their projects are in trouble and that they must trust outside entities more because the knowledge needed for the project cannot be found inside the team. Interestingly, in the most successful projects, the positive effect of relational capital was greater on knowledge combination. It seems that there is a feedback loop in the relationship between relational capital and project success: as a project becomes more successful, the team members trust each other more, and as trust improves, so does the likelihood of project success.

There was no difference in the effect of team cognition on knowledge combination between the most and least successful projects. There was, however, a significant difference between groups regarding the effect of team cognition on knowledge exchange. It is likely that more successful project teams have learned how to manage team cognition to their advantage. Future research should explore this interesting result in more depth to see if team cognition determines whether a project succeeds or fails.

Regarding the impact of project uncertainty, the negative impact of uncertainty on both knowledge exchange and combination was significantly stronger in the most successful projects than in the least successful projects. This means that as uncertainty increases, both knowledge exchange and combination decrease, more so in the most successful projects than in the least successful ones. This result, although non-conventional, can also be explained using the information-processing perspective. It seems that successful projects, when faced with increased uncertainty, might recognize that more team-level exchange and combination of information may be counterproductive to their information-processing capabilities [66], [22]. Therefore, they delegate project tasks to small sub-groups within the team, which are knowledgeable about the specific domain of uncertainty. These sub-groups may be able to reduce the uncertainty to a level where team-level knowledge exchange and combination become viable again.

In context of knowledge combination, it is interesting to note that the moderating effect of uncertainty is not only significantly different but also opposite between the most and least successful projects. Thus, as uncertainty increases, teams engaged in successful projects increased their use of IT to combine their knowledge resources. The results, although counter-intuitive for knowledge combination, which is primarily considered to be a less IT-dependent process, seem to indicate that successful teams may have learned to use interactive technology to collaborate, discuss, debate, and perform other communicative activities with similar effectiveness as face-to-face communication.

Teams associated with the least successful projects, however, showed a negative moderation effect, indicating that as uncertainty increases, IT use for knowledge combination decreases. This finding is expected for less successful projects.

5.2. Limitations

Certain limitations of this study need to be noted. The fact that the research was conducted with software development teams may limit the generalization of the results beyond that scope. There is also a cultural issue associated with the study, as the data were collected in Indian software companies. However, the results may still apply to other knowledge-intensive firms with team-based structures. Nevertheless, caution must be exercised in generalizing beyond the type of firms used in this study.

Second, the study did not include all team-, project-, or IT-related antecedents to knowledge exchange and knowledge combination. Finally, the use of perceptual survey measures for data collection might increase the risk of common-method bias. The data were only collected from one individual for each project that was the level of analysis in the study. In addition, although the survey method is useful in identifying relationships, it does not inform us about why these relationships exist. That information is more likely discovered in qualitative analysis.

5.3. Implications for research

The study makes three novel contributions to the literature. First, much of the literature on knowledge processes focuses on a chain of events beginning with the acquisition of knowledge and ending with the use of the acquired knowledge, despite the explicit or implicit separation of these processes in prominent knowledge management frameworks [23], [1]. This study contributes to the literature by providing empirical evidence that knowledge exchange and combination are different processes and that future studies should examine them separately. Additionally, this study extends this contribution to the information systems literature by providing empirical evidence that IT use intensity has different effects on knowledge exchange and combination.

Second, this study integrates the knowledge management literature and the project uncertainty literature by examining uncertainty as a moderator between IT use intensity and the knowledge management processes of exchange and combination. To the best of our knowledge, no prior study has evaluated the team-level relationship between technology use and knowledge processes in light of uncertainty, which is a critical risk factor in most software projects. The interesting and unexpected results shed new light on the complex influence that project uncertainty has on key software development processes. This not only confirms the status of uncertainty as a confounding environmental variable in software projects but also adds to our understanding of how critical knowledge management activities respond to uncertainty.

Finally, the study also contributes by examining each of the aforementioned areas in the context of the least and most successful software development projects. This detailed analysis helped uncover nuanced details in our results that were not evident in the overall analysis.

5.4. Implications for practice

Our findings raise some interesting issues with regard to practice. First, they suggest that the frequency of IT use has significant effects on both knowledge exchange and knowledge combination. It is important that organizations support teams by facilitating technology, but this is particularly true of technology to facilitate the knowledge exchange process. Systems that allow team members to search for and retrieve crucial knowledge such as previously developed code, standards, and other items that team members do not possess increase the effectiveness of knowledge exchange. However, technology that facilitates the team members' coordination with individuals outside the team also increases knowledge exchange. Successful projects benefit more in terms of knowledge exchange from an increased use of IT. Our results also indicate that an increased use of IT leads to higher levels of knowledge exchange or combination for the most successful projects under conditions of high uncertainty. Thus, it may be important for organizations to review both successful and less successful projects for differences in IT use and to train teams to effectively use IT.

5.5. Future research

The findings of this study set the stage for future research using the social capital theory and IT. Researchers should consider the inclusion of IT along with other components of the structural dimension in examining any relationships with variables such as knowledge creation, knowledge sharing, organizational learning, or other similar concepts. Future studies can conduct a comparative examination of these issues across other types of teams, such as new product development teams or R&D teams.[2]

Social capital theory presents two concepts that would be useful in further investigating the relationship between IT and knowledge exchange and combination. These two concepts are "network ties" and "network configuration." The concept of network ties as a proposition of social capital theory [53] might act as mediator between IT and knowledge variables. The benefits from network ties in creating social capital include access, timing, and referrals. All of these variables are logical extensions to this study and may be examined as mediators in the relationship between IT and knowledge exchange and combination. Future studies might also consider including network configuration factors such as density, connectivity, and hierarchy [53]. All of these could be viewed as characteristics of IT and could be examined as variables in the relationship between IT and knowledge exchange and combination.

Additionally, given the unexpected results of the impact of uncertainty on the knowledge-sharing processes, it would be interesting to find out why project teams act contrary to the existing wisdom when faced with uncertainty. Is there a threshold that uncertainty must pass before this effect is observed? Are there different types of uncertainty that might trigger this negative effect while some other types might have the expected positive relationship?

6. Conclusion

Our research examines the concepts of knowledge exchange, knowledge combination, IT use intensity, and project uncertainty in software project teams. We contribute to the literature in these areas by showing that (1) the frequent use of IT has an effect on the knowledge processes of exchange and combination, (2) the effect of technology use intensity is stronger on knowledge exchange than on knowledge combination, and (3) the effect of technology use intensity is stronger for most successful projects in the context of knowledge exchange.

Our study also examines the moderating effects of uncertainty on the above relationships. Our major contributions are that (1) teams engaged in successful projects increase IT use intensity as uncertainty increases in the context of both knowledge exchange and combination and (2) teams engaged in the least successful projects do not modify their IT use as uncertainty increases in the context of knowledge exchange but decrease their use of IT as uncertainty increases in the context of knowledge combination.

In addition to the above contributions, the results of this study support separating knowledge exchange from knowledge combination and the least successful project outcomes from the most successful project outcomes. This research enables practitioners to strategically allocate IT resources to maximize the goals of the organization in terms of knowledge processes and gives researchers a basis on which to continue studying the intricacies of the relationships between knowledge processes and IT.

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[2] We would like to thank one of the reviewers for this input.

Appendix A.

Knowledge exchange

If the required knowledge was not available within the team, members acquired that knowledge from external sources.

Team members often reused codes available from other projects.

Team members often enhanced their knowledge with inputs from external sources.

Knowledge combination

Team members combined their individual expertise to jointly solve project-related problems.

Team members combined their individual perspectives to develop shared project concepts.

Team members often gained new insights by sharing their ideas with each other.

Team members improved their task efficiency by sharing their knowledge with each other.

Information Technology Use Intensity

Compared to other teams you have led:

This team uses IT-based systems MORE to search for project-related knowledge.

This team uses IT-based systems MORE to retrieve project-related knowledge.

This team uses collaborative systems MORE to internally coordinate project-related tasks.

This team uses IT-based systems MORE to coordinate with others in the company.

Requirements Uncertainty

Compared to other projects:

There was more confusion in the project about developing software that would meet the requirements specification.

Established procedures and practices could not be relied upon in that project to develop software that would meet the requirements specifications.

An understandable sequence of steps could be followed in that project to develop software that would meet the requirements specifications.

Outcome uncertainty

Compared to other projects:

The outcomes of this project were more unpredictable.

It took more time to foresee the outcomes of this project.

It was more difficult to understand the outcomes of this project.

Cognitive capital

Members of the team varied widely in their areas of expertise.

Members of the team had a variety of different backgrounds and experiences.

Members of the team had wide-ranging skills and abilities.

Relational capital

The team was characterized by personal relationships among members at multiple levels.

The team was characterized by high levels of reciprocal behavior among members at multiple levels.

The team was characterized by mutual trust among members at multiple levels.

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