Knowledge processes in virtual teams: consolidating the evidence

Abstract

This article takes stock of the current state of research on knowledge processes in virtual teams and consolidates the extent research findings. Virtual teams, on the one hand, constitute important organizational entities that facilitate the integration of diverse and distributed knowledge resources. On the other hand, collaborating in a virtual environment creates particular challenges for the knowledge processes. The article seeks to consolidate the diverse evidence on knowledge processes in virtual teams with a specific focus on identifying the factors that influence the effectiveness of these knowledge processes. The article draws on the four basic knowledge processes outlined by Alavi and Leidner (2001) (i.e., creation, transferring, storage/retrieval and application) to frame the investigation and discuss the extent research. The consolidation of the existing research findings allows us to recognize the gaps in the understanding of knowledge processes in virtual teams and identify the important avenues for future research.

1. INTRODUCTION

The globalization of business competition and a growing need for customer responsiveness in the past few decades have caused an increasing number of firms to undergo dramatic organizational changes (Miles & Snow, 1992). Organizations transform to networks by flattening organizational structure and establishing inter-organizational links (Davidow & Malone, 1992). This change has promoted contemporary firms to coordinate activities that span geographical and organizational boundaries (Townsend et al., 1998). It has also increased the need for utilizing decentralized, specialized knowledge and expertise (Alavi & Tiwana, 2002; Boutellier, 1998; Penrose, 1959). Virtual teams have emerged to allow organizations to overcome these geographical boundaries and to address the emerging knowledge needs (Powell et al., 2004; Workman, 2007).

Virtual teams constitute essential structures in today's organizations (Siebdrat et al., 2009). An internal virtual workforce survey of twelve hundred employees in Intel Corporation reveals that approximately 70 percent of the Intel workforce collaborates with people in different time zones without meeting face to face (Intel Corporation, 2004). Accenture, an international IT systems consulting firm, rests its viability on the performance of "customer-intimate" project teams coordinated among dispersed sites (Accenture., 2005). Virtual teams form an essential part of today's organizations with important implications for teamwork and collaboration.

A crucial aspect of virtual teams is the knowledge process among the team members. In fact, the main driver for building virtual teams is the prospect of integrating the dispersed knowledge and expertise of the team members (Alavi & Tiwana, 2002; Boutellier, 1998). However, while virtual teams are established to support knowledge integration it has been recognized that the virtual collaboration environment inhibits the team's knowledge

processes. The geographic dispersion and the reliance on information technologies hinder team members to create, transfer, store and apply knowledge (Alavi & Tiwana, 2002; Cramton, 2001; Griffith et al., 2003). Studies in innovation management (Ahuja, 2000) and organizational learning (Walsh, 1995) highlight how the distributed nature of cognition and the diversity of knowledge in team settings creates challenges for team learning and knowledge processes. These challenges become even more pronounced when the interaction among teams are virtual (Alavi & Tiwana, 2002).

Virtual teams are in a "catch-22" situation: the opportunities of integrating dispersed knowledge promotes the emergence of virtual teams; at the same time virtual teams are arguably less capable of identifying and leveraging the collective knowledge of their members than traditional teams are. Recognizing this paradox is highly important for virtual team members as effective knowledge exchange and utilization is not achieved until the team has identified ways for managing the diverse knowledge processes.

Although a range of studies on knowledge processes in virtual teams has been undertaken, the emerging body of research lacks a common basis that puts the different contributions into perspective with each other. Contributions originate from domains as diverse as organizational behavior, information science or innovation studies with each study adopting individual perspectives, models and variables. The diversity of contributions makes it increasingly difficult to establish what is already known about the knowledge processes of virtual teams and to isolate the remaining research questions. In order to advance research on knowledge processes in virtual teams and to support further targeted work in the area, we have set out to address the question of: *What factors influence the effectiveness of knowledge processes in virtual teams?* We review and consolidate the extant literature to identify factors that influence knowledge process effectiveness, which is defined as the extent to which

knowledge processes support a team in fulfilling its objective (following the established notion of team process effectiveness (Dean & Sharfman, 1996). By developing an overarching framework that integrates the extent research our work has the potential to rapidly fill the gaps in the understanding of knowledge process issues in virtual teams and help move forward research and practice in the field.

The paper is organized as follows. First, we present the overarching framework to structure the knowledge processes in the extant empirical literature. Second, we organize previously published papers in terms of the framework and review the factors influencing the knowledge processes in virtual teams. Finally avenues for future research are discussed.

2. RESEARCH ON KNOWLEDGE PROCESSES IN VIRTUAL TEAMS

The significance of knowledge processes for virtual teams is characterized by three core arguments. First, knowledge processes of virtual teams have important implications for organizational and individual learning. The organizational learning literature has stressed that the team is the fundamental learning unit in an organization (Edmondson, 1999; Senge, 1990) and a major mechanism for integrating its knowledge resources (Grant, 1996). Teams are also important for individual learning in that individual cognition and behavior is shaped by the social context in which people work (Edmondson, 2002; Hackman, 1992). This perspective is also highlighted in studies on the group-to-individual transfer of learning (Olivera & Straus, 2004).

Second, virtual teams have assumed an increasingly important role in leveraging and integrating knowledge across geographically dispersed organizations. Virtual teams play a critical role in productive work (such as innovation, Leonard & Sensiper, 1998; Malhotra et al., 2001), in reacting to a shortage of expertise (caused by today's trends toward downsizing,

globalization), and in addressing employees' preference for increased mobility and flexibility (Markus et al., 2000; Townsend et al., 1998).

Third, a goal of virtual teamwork should be to accomplish tasks more effectively by making better use of available knowledge. Consequently, research examining virtual teamwork must view learning and knowledge as a means, rather than a goal in itself, as shown in the distance-learning literature (e.g. Alavi & Leidner, 2001). Given the significance of knowledge related issues in virtual teams, the current body of research on this topic should be preserved and future research directions need to be identified.

While other literature reviews on virtual teams have been carried out (Hertel et al., 2005; Martins et al., 2004; Pinsonneault & Caya, 2005; Powell et al., 2004; Saunders, 2000), and publications have conceptualized the implications of virtual team environments on knowledge work (Assudani, 2009; Bosch-Sijtsema et al., 2009) no major review analyzing and integrating the diverse empirical studies on knowledge processes within virtual teams has been published to date. As the enabling of knowledge processes is one of the core motivations of forming virtual teams we address this gap by reviewing the existing research in the context of virtual teams.

3. A FRAMEWORK OF KNOWLEDGE PROCESSES

Our review is built on the basis of a framework of four knowledge processes identified by Alavi and Leidner (2001). According to this framework, organizations represent knowledge systems consisting of four sets of socially enacted knowledge processes: (1) creation, (2) storage/retrieval, (3) transfer and (4) application. The focus on social collectives as knowledge systems is grounded in the sociology of knowledge (Berger & Luckmann, 1967; Gurvitch et al., 1971; Holzner & Marx, 1979) which considers groups and its members' interactions as the critical unit for knowledge process analysis.

Knowledge creation describes changes in an individual's mental models or knowledge representations. According to this definition, learning involves the acquisition of knowledge and changes in knowledge structures rather than a behavior per se (Grant, 1996; Greeno, 1974; Kwok et al., 2002). Thus, *knowledge creation* is essentially a process of acquiring knowledge in order to create new knowledge. Alavi and Leidner's (2001) notion has some limitations, as it considers knowledge creation as a homogenous process whereas other scholars have elaborated on diverse facets within the knowledge creation process (Argyris & Schon, 1978; Kolb & Fry, 1975). *Knowledge transfer* refers to the process of conveying knowledge to locations or individuals where it is needed and can be used (Alavi & Leidner, 2001) often with the help of repositories or other technology based systems (Wu et al., 2010). *Knowledge storage/retrieval* refers to the process of collecting knowledge and making it accessible, commonly requiring steps of encoding and decoding the knowledge resource (Gammelgaard, 2010). Finally, *knowledge application* in the form of task teams refers to the application of knowledge for problem solving (Grant, 1996).

Our choice of Alavi and Leidner's (2001) framework to structure our review of knowledge processes in virtual teams is justified by its parsimony and wide-spread application in the IS domain. Although other frameworks are available (see Rubenstein-Montano, 2001), Alavi and Leidner's (2001) focus on four major knowledge processes provides a level of granularity that allows for subsequent pattern analysis (Peachy et al., 2005). It is widely used to conceptualize comprehensive knowledge process investigations (e.g. Palanisamy, 2007) or to define individual processes (e.g. Choi et al., 2010; Lee & Choi, 2003). Focusing on Alavi and Leidner's (2001) framework to structure our assessment of the literature on knowledge processes in virtual teams increases the utility of our investigation and allows us to add to the cumulative research on knowledge processes (Guo & Sheffield, 2008; Keen, 1980).

4. METHODOLOGY FOR LITERATURE SELECTION

Three means were used to identify relevant articles concerning knowledge processes in virtual teams. First, and consistent with prior formal literature reviews published (Martins et al., 2004; Pinsonneault & Caya, 2005; Powell et al., 2004), a computer search using ABI/INFORM was conducted, and search results were manually screened to eliminate irrelevant hits. ABI/INFORM is widely regarded as the most comprehensive online portal for academic papers, and has been used for literature reviews in existing studies (Powell et al., 2004). We included as many relevant studies as possible by relaxing search criteria to obtain a wider range of articles related to knowledge processes in virtual teams. More precisely, we used "virtual/dispersed/non-collocated/computer-mediated/IT-mediated" as keywords to search through abstracts. In the same logic, we used "team/group" to capture the notion of team. While acknowledging that teams and groups are different in terms of task interdependence, the two terms are often used interchangeably in traditional and virtual team research (Cohen & Bailey, 1997; Langfred, 1998). To capture knowledge issues in virtual teams, "learning/knowledge/innovation/problem solving" were used as keywords to search in article abstracts for hints on knowledge processes. Among these keywords, innovation in virtual teams commonly represents knowledge acquisition and knowledge application processes, whereas problem-solving may capture knowledge application processes (Alavi & Tiwana, 2002). We focus on keywords within abstracts only because we assume that an article does not concern with knowledge issues in virtual teams if it doesn't have the defined keywords in its abstract, as the abstract summarizes the major research questions, methods and findings.

Another major source are literature review articles, such as Powell et al (2004), Martins et al. (2004) and Hertel et al (2005) and their extensive references. We examined the reviews and identified 11 papers dealing with issues of knowledge processes in virtual teams. Thirdly, we

referred to resources on virtual teams located on the ISWORLD website, and identified 4 papers concerning knowledge processes in virtual teams.

All articles identified were read to determine if the issue and the unit of analysis met our search criteria (i.e., knowledge transfer, knowledge application, knowledge creation, and knowledge storage/retrieval in geographically dispersed teams). It was also confirmed that the described knowledge processes met the widely accepted definitions originally provided by Alavi and Leidner (2001). 33 papers were ultimately identified as meeting the criteria for inclusion and were analyzed in the literature review. All journal papers identified are published in SCOPUS-listed journal outlets with more than 80% of the papers ranked in the first two quality quartiles in their respective subject categories (based on the SNJ index, González-Pereira et al., 2010). These papers are categorized in detail in Appendix 1 (their references form part of the list of references of this paper).

5. LITERATURE ANALYSIS ON KNOWLEDGE PROCESSES IN VIRTUAL TEAMS

In the current section, we first explore which knowledge processes have been studied by categorizing the 33 papers according to Alavi and Leidner's (2001) framework. We manually screened all papers to examine the team-based knowledge processes that each paper focuses on. Following our research question we identified the major issues that impact on these knowledge processes and categorize them according to the input-process-output model. The input-process-output model is the dominant framework used in studies of teams and provides a sound basis for organizing and integrating the literature on Virtual Teams (VT) (Martins et al., 2004; Pinsonneault & Caya, 2005; Powell et al., 2004). We identify two broad categories of factors impacting on the knowledge processes within teams: input factors and process factors. *Input factors* refer to a priori features that a team has upon its formation. *Process*

factors refer to emerging aspects that influence the practice among team members. The review has shown that virtual team research has considered both input and process factors with their impact on the team's knowledge processes.

The specific range of input and process factors encountered in the analysis focus on the team's information technology, member configuration, socio-cognitive properties and specific interventions. Information technology related factors cover aspects of technology choice but also aspects of technology use. Member configuration factors are largely conceptualized as input factors and include aspects such as team dispersion, virtualness or the diversity of experiences present among team members. In contrast, factors related to the team's socio-cognitive properties, such as trust or transactive memory, were largely considered as process factors (emerging within the team). The range of specific interventions considered with their impact on the team's knowledge processes include factors like training or leadership initiatives.

The literature review has revealed that all four knowledge processes (creation, storage, transfer, application) have been investigated in the existing virtual team literature. The most studied KM process is knowledge transfer (16 articles), while the least studied is knowledge storage/retrieving (2 articles). Knowledge creation (10 articles) and knowledge application (10 articles) in virtual teams have been moderately studied. Most of the papers (i.e., 24 papers) focus on only one knowledge process while six cover two knowledge processes (Haas, 2006; Majchrzak, Rice, King, et al., 2000; Majchrzak, Rice, Malhotra, et al., 2000; Malhotra & Majchrzak, 2004; Malhotra et al., 2001; Robert et al., 2008), and one covers three KM processes (Paul, 2006). Table 1 presents a high-level summary of the major input and process factors identified as impacting on the knowledge processes of virtual team, as well as the theories and methods that appear in each category. The listing of the theories and

methods indicate the predominant research perspectives and data collection methods employed so as to obtain a more comprehensive understanding of the specific range and nature of studies investigating each particular knowledge process. The next section focuses on each knowledge process in detail and discusses how the knowledge processes are impacted by the different input and process factors identified.

Table 1: Summary of Articles on knowledge management processes in Virtual Teams

Knowledge processes	Articles	Factors influencing effectiveness (#)	Theories (#)	Methods (#)
Knowledge Creation (10 articles)	(Alavi et al., 2002) (Ocker & Yaverbaum, 1999) (Capece & Costa, 2009) (Robey et al., 2000) (Vogel et al., 2001) (Alavi, 1994) (Qureshi & Vogel, 2001) (Haas, 2006) (Majchrzak et al., 2005) (Paul, 2006) (Vaccaro et al., 2009)	Input: IT use (3); Choice of IT tools (1); Learning interveners (1); Diversity of member experience (1); Structural configuration (1) Process: Situated learning (1); Collaborative know-how development (1)	- Technology-mediated learning (1); - Computer-mediated communication (1); - Situated learning (1); - Socio-cultural learning (1); - Social learning theory (1) - Structuration theory (1) - Cognitive-affective model (1) - Knowledge creation model (SECI) (1)	-Qualitative interview (1); - Case study (3); - Experiment (2); -Survey (2) (2 conceptual papers) -Social network analysis (1)
Knowledge Transfer (12 articles)	(Griffith et al., 2003) (Behrend & Erwee, 2009) (Cramton, 2001) (Griffith & Neale, 2001) (Yoo, 2001) (Sole & Applegate, 2000) (Majchrzak, Rice, King, et al., 2000) (Majchrzak, Rice, Malhotra, et al., 2000) (Malhotra et al., 2001) (Malhotra & Majchrzak, 2004) (Sole & Edmondson, 2002) (Baba et al., 2004) (Paul, 2006) (Chang, 2008) (Ratcheva, 2009) (Staples & Webster, 2008) (Robert et al., 2008), (Kim & Jarvenpaa, 2008)	Input: training, team dispersion virtualness, IT use, team structure (6); Task demand (1) trust, virtualness, task characteristics (1) Social capital (2) Process: Shared understanding, transactive memory, mutual understanding, situated knowledge, technology use norms, coherence (6); Cognitive Convergence (1) embeddedness, knowledge sharing obligations (1) Boundary spanning (1) Output: team effectiveness (1) Team decision quality (1)	- Communication theory (5) - Transactive memory (1) - Social cognitive literature (1) - Theory of shared meaning (1) - Adaptive Structuration Theory (1) - Situated learning (1), Psychological contract theory (1), Social exchange theory (1), Social capital (1)	- Document analysis (1) - Experiment (2) - Survey (3) - Case study (8) (3 conceptual papers)

Knowledge Storage/ Retrieving (2 articles)	(Malhotra et al., 2001) (Majchrzak, Rice, Malhotra, et al., 2000)	Input: The role of knowledge manager (1); Output: Usefulness of knowledge repository (1)	- Communication literature (1) (used only to develop opposing hypotheses)	- Case study (2)
Knowledge Application (9 articles)	(Majchrzak, Rice, Malhotra, et al., 2000) (Alavi & Tiwana, 2002) (Boutellier, 1998) (Kruempel, 2000) (Archer, 1990) (Malhotra & Majchrzak, 2004) (Haas, 2006) (Gibson & Gibbs, 2006) (Paul, 2006) (Robert et al., 2008)	Input: Comparison b/w VT and TT (3); Leader (1); Use of IT (1); Diversity of member international experience (1); Virtualness (1) Social capital Process: Transactive memory (1) Mutual understanding (1) Structural change in process (2) Output: Team decision quality	- Structuration theory (5) - Communication theory (2) - Social information processing (1) Social capital (1)	- Experiment (4) - Case study (2)

#: Number of papers

Knowledge creation

Knowledge creation is the process of learning that changes team members' mental models or knowledge representations to produce new knowledge. Research to date has touched upon the effect of using information technology on team knowledge creation (Alavi, 1994; Alavi et al., 2002; Ocker & Yaverbaum, 1999; Vaccaro et al., 2009) and collaborative know-how development (Majchrzak et al., 2005), situated learning in a virtual environment (Robey et al., 2000), the factors that enable knowledge creation (Capece & Costa, 2009; Vogel et al., 2001), and the benefits of acquiring knowledge in virtual teams (Saunders, 2000).

Input factors: First, the existing studies have examined how team dispersion facilitates the creation effectiveness by comparing dispersed teams and face-to-face teams. The findings suggest that computer-mediated learning can be as effective as face-to-face learning (Ocker & Yaverbaum, 1999). Second, early studies encountered mixed evidence concerning the effect of using advanced information systems on knowledge creation. On the one hand, it is

found that the learning outcome of virtual teams supported by advanced Group Systems is superior to non-supported virtual teams (Alavi, 1994). It is suggested that advanced information structuring and facilitated exposure to diverse perspectives provides superior basis for mental model development On the other hand, it was found that virtual teams using email perform better than advanced IT-supported teams in a learning environment (Alavi et al., 2002). The reason might be that cognitive load required for mastering advanced information systems is much higher than that for email; therefore members' remaining cognitive resources to learn are reduced in virtual teams with advanced IT (Alavi et al., 2002). Third, recent literature looked at how virtual team composition (e.g., locals versus cosmopolitans) (Haas, 2006) and structural configuration (Capece & Costa, 2009) influences a team's knowledge creation process which is explained by the different communication structures that emerge among team members.

Process factors: Vogel et al (2001) identify nine enabling process factors analyzing the cases of seven virtual teams (e.g., assisted learning, cognitive apprenticeship). Communities of practice and situated learning are regarded as important means to facilitate knowledge creation by embedding good practices (Robey et al., 2000). Majchrzak et al. (2005) found collaboration know-how development to be an instrumental process that facilitates knowledge creation as it contributes to idea communication and integration with other members. Vacarro et al (2009) were able to show that Nonaka's prominent SECI model of knowledge creation (socialization, externalization, internalization, combination) is a valid model to depict the knowledge creation process in virtual teams.

Knowledge transfer

Knowledge transfer refers to the transmitting of knowledge to locations where it is needed and can be used (Alavi & Leidner, 2001). To capture the knowledge transfer process the

literature has focused on the communication process between team members, the extent and quality of the exchanges and the factors that impact these.

Input factors: Different factors have been identified to influence communication processes within virtual teams. Virtualness, defined as time that team members spend apart on tasks, is suggested to negatively influence collective knowledge and shared understanding (Griffith et al., 2003), and to negatively influence development of a shared cognitive structure (Griffith & Neale, 2001). The negative influence is explained by the diminishing level of integration and loyalty between employee and organization in highly virtual teams. Training that targets the development of communication and media competencies is suggested to be useful in enhancing coherence within virtual teams (Cornelius & Boos, 2003). Staples et al (2008) have pointed out that hybrid teams (partly collocated) risk the creation of in-groups which create an even higher impediment to knowledge sharing than an overall high degree of virtualness. For highly innovative virtual teams that are innovating in both process and team tasks, keeping a malleable structure that can evolve over time is important for completion of the innovative task (Majchrzak, Rice, Malhotra, et al., 2000; Malhotra et al., 2001).

Another structural input factor is the use of information technologies. The use of collaborative technology has been suggested to moderate the effect between team virtualness and shared understanding (Griffith et al., 2003) as such technology contributes to the development of a shared cognitive structure. Majchrzak et al (2000) in turn suggest that such shared cognitive structures allows teams to use information technology effectively even for highly complex knowledge transfers.. However, not all types of information technologies are suitable for knowledge transfer: paradoxically, overly rich media such as video conferencing facilities are not perceived as effective in transferring explicit knowledge as too may communication cues distract from the content (Paul, 2006).

Process factors: The existing literature has achieved consensus that an effective communication process within virtual teams is essential to knowledge transfer and subsequently to team performance (Cornelius & Boos, 2003; Cramton, 2001; Griffith & Neale, 2001; Griffith et al., 2003; Sole & Applegate, 2000). A number of factors facilitating effective communication have been identified, including shared understanding/mutual knowledge (Cornelius & Boos, 2003; Cramton, 2001; Griffith & Neale, 2001; Griffith et al., 2003), collective knowledge/collective mind (Griffith et al., 2003; Yoo, 2001), transactive memory (Griffith & Neale, 2001; Griffith et al., 2003; Yoo, 2001), psychological contracts (Chang, 2008), trust (Staples & Webster, 2008), conversational coherence (Cornelius & Boos, 2003) and technology use norms (Sole & Applegate, 2000). Shared understanding, mutual knowledge and mutual understanding all refer to a similar notion–knowledge that the communicating parties have in common (Krauss & Fussel, 1990), or more broadly as "common ground" (Clark & Carlson, 1982), which are similar to episodic memory in Alavi and Leidner's (2001) framework. Research has suggested that this kind of tacit team-level knowledge is essential to team performance, such as satisfaction (Cornelius & Boos, 2003), viability and decision making quality (Cramton, 2001) as it facilitates the effective communication among virtual team members.

Collective knowledge (or collective mind) refers to explicit knowledge that has been internalized by the team members, such as teamwork procedures (Griffith et al., 2003). It is different from shared understanding in the sense that shared understanding is more implicit (Griffith et al., 2003).. Technology use norms can be considered a particular instance of collective knowledge (Sole & Applegate, 2000), referring to shared knowledge of using a particular technology in the team. By facilitating the interaction among team members technology use norms positively influence knowledge sharing practice and subsequently influence team performance (Sole & Applegate, 2000).

Transactive memory is a shared system for encoding, storing, and retrieving knowledge available to the group (Griffith et al., 2003). It captures the team members' meta-knowledge about who knows what in the team (Yoo, 2001). Transactive memory have been suggested to moderate the relationship between communication volume and team performance (Yoo, 2001) and influences a teams' utilization of potential knowledge (Griffith et al., 2003) as a shared knowledge base allows team members ready access to particular expertise.

While the above factors have been shown to impact the team members' ability to transfer knowledge among each other there is little consideration of the fact that knowledge sharing is mostly a voluntary and discretionary activity. Although team members are able to transfer knowledge they can decide not to. Hence, the level of trust (Staples & Webster, 2008) and the development of mutual obligations (psychological contracts) (Chang, 2008) among virtual team members impact on the knowledge sharing activity among members of a virtual team.

Knowledge storage and retrieving

Knowledge storage and retrieval largely refers to the practice of codifying knowledge in technology-based systems. While the appropriate knowledge management systems are widely distributed and available to different organizational members (Maier, 2007), our review found only two studies that have specifically looked at knowledge storage and retrieval in virtual teams. One study has found that codified knowledge saved in the knowledge repository is unlikely to be appropriately referenced for later search and retrieval (Majchrzak, Rice, Malhotra, et al., 2000). Storing too much knowledge items within team's electronic knowledge repository can also make the knowledge retrieval difficult due to information overload (Malhotra et al., 2001). To avoid such problem, virtual team members and managers can rely on norms for knowledge storage and codification, thereby allowing for valuable

information to be archived, and for more efficient usage of embedded search tools (Malhotra et al., 2001).

Knowledge application

Research to date on knowledge application has looked at structural factors and communication factors that influence team knowledge application in the form of problem solving. The structural factors include leadership effect (Kruempel, 2000), use of IT (Archer, 1990; Boutellier, 1998; Chidambaram & Jones, 1993; Sharda et al., 1988) and team structure (Clear & Daniels, 2000; Majchrzak, Rice, Malhotra, et al., 2000).

Input factors: Krumpel (2000) suggests that virtual teams with an effective leader are more capable of applying knowledge in a way that helps them solve organizational problems since ownership and responsibility are clearly allocated. Concerning computer mediation, Boutellier (1998) suggests that intensive use of information technology enables virtual R&D teams to work more efficiently and effectively. Majchrzak et al (2000) suggest that a malleable structure for highly innovative teams is important for successful completion of innovative tasks. Not surprisingly, research has also revealed that teams with high degree of virtualness (e.g., geographical dispersion, temporal difference) may encounter obstacles in applying knowledge for innovation which is linked to the difficulties of establishing a safe communication environments in a virtual context (Gibson & Gibbs, 2006). Also, the nature of the task has an influence on the effectiveness of knowledge application and integration. If a task is perceived as intellectually challenging and is highly contextualized, knowledge integration among team members is most effective (Paul, 2006).

Process factors: Alavi et al (2002) suggest that transactive memory, mutual understanding, contextual knowledge and flexibility of organizational ties are all important for knowledge application within virtual teams, and knowledge management systems (KMS) should be

designed to address these factors. An environment in which communication is characterized by openness, trust, support, respect, and risk taking, is found to be an important factor moderating the effectiveness of knowledge application for innovation (Gibson & Gibbs, 2006). The development of social capital contributes to the team members use of knowledge of each other (Robert et al., 2008), an observation which has implications for those studies that are based on ad hoc teams to provide evidence on knowledge application aspects.

In addition, the existing literature has compared the quality of problem solving between traditional teams and virtual teams. The findings suggest that virtual teams end up with higher performance (Sharda et al., 1988), or at least not worse (Archer, 1990; Chidambaram & Jones, 1993). However, virtual teams take longer to accomplish tasks (Archer, 1990; Sharda et al., 1988).

6. DISCUSSION AND RECOMMENDATIONS FOR FUTURE RESEARCH QUESTIONS

The analysis has identified a considerable diversity of factors that influence knowledge processes in virtual teams. We will now draw on this analysis to shed light on important aspects of virtual team knowledge processes that, to date, still remain under-explored and to provide research questions to guide future work in the area. The analysis is organized in accordance with the four knowledge processes with the core research questions summarized in Table 2.

Table 2 – Recommended Future Research Questions

Knowledge process	Areas for Future Research
Knowledge Creation	What are the influencing factors of effective on-job learning/training within virtual teams? What are the cumulative and opposing effects on knowledge creation in virtual teams and how can these factors be balanced out by management initiatives?
Knowledge	How does the motivational disposition of knowledge receiver and

Transferring	sender impact on the knowledge sharing process within virtual teams?
Knowledge Storage/Retrieving	Which skills and traits are required by a knowledge manager to successfully facilitate knowledge storage in virtual teams? Which factors influence the quality of a knowledge repository developed in virtual teams?
Knowledge Application	How do the processes of knowledge creation, knowledge sharing, and knowledge storage contribute to knowledge application? How do the levels of IT use and other context components impact on the levels of knowledge application within virtual teams?
Combination of the Four KM Processes	Whether and how do structural and process factors of virtual teams differ in their effects on different knowledge processes?
Multi-Level Research	What implications do knowledge processes at the team level have on individual and firm level performance? How do new developments in communication technology and collaboration practices impact on knowledge processes of virtual teams?

Questions on knowledge creation

Early virtual team research has paid significant attention to knowledge creation as the final objective of team activities. Most of the studies examine knowledge creation as a team task (Alavi, 1994; Alavi et al., 2002; Ocker & Yaverbaum, 1999; Qureshi & Vogel, 2001). However, such a team task setting seldom happens to virtual teams in real organizations. Instead, virtual teams are formed to solve a practical problem by integrating team members' current knowledge, skills and ability (Powell et al., 2004). In most cases, knowledge creation is a by-product of teamwork. That is, teams themselves often become the "training grounds for the acquisition of new skills and knowledge areas" (Cianni & Wnuck, 1977, p. 106). Consequently, to facilitate team members' on-job knowledge creation is of considerable importance as the knowledge is particularly relevant and context-specific, thus possessing high value for the team. Given the importance and prevalence of this mode of knowledge creation future studies should not only investigate knowledge creation per se, but to focus on the *factors that facilitate on-job-learning 'as a by-product' of a task completion.*

Another important observation that emanated from the literature review refers to the diversity of factors that impact on the knowledge creation process within virtual teams. While some of these factors contribute to the knowledge creation process (e.g. collaboration know how) others inhibit the knowledge creation process (e.g. information systems requiring advanced cognitive processes). With research so far having largely focused on these factors in isolation virtual team managers cannot focus on individual factors but need to be able to consider the complex web of dependencies which are created by these diverse factors. To be able to provide further implications for practice future research should focus on identifying the *cumulative or opposing effects* of these diverse factors with particular attention to the pro-active balancing of these *effects to better support knowledge creation within virtual teams*.

Questions on knowledge transferring

The existing literature emphasizes on knowledge transfer processes but has largely overlooked agents who send or receive knowledge that is transferred. Szulanski (1996) suggests that knowledge flows can be conceptualized as a function of five factors based on communication theory, including 1) perceived value of the source knowledge; 2) motivational disposition of the source; 3) existence and richness of transmission channels; 4) motivational disposition of the receiver; 5) the absorptive capacity of the receiver. Given the importance of communication technology for knowledge transfer in virtual teams research has largely looked at existence and richness of transmission channels (e.g., IT as a means of communication) and ways to recognize perceived value of the source knowledge (e.g., mutual understanding, transactive memory); hardly any attention has been paid to the other three elements (i.e., motivational disposition of receiver and sender, absorptive capacity of the receiver), which are all deemed essential in knowledge transfer (Govindarajan, 2000) and which should not be overlooked due to a focus on the technology artifact. Yuan (2011)

showed how sympathy towards others impacts on knowledge sharing behavior. To better understand the knowledge transfer process among virtual team members requires a focused *investigation of the motivational disposition of knowledge receiver and sender, as well as the role of the knowledge receiver's absorptive capacity.*

Questions on knowledge storage/retrieving

The lack of contributions focusing on knowledge storage and retrieval processes in the virtual team context is of particular interest. A possible explanation is that the explicit knowledge storage and retrieval as defined by Alavi and Leidner (2001) does not represent a core process in virtual teams. As the majority of exchanges among team members are carried out in a codified format automatically (e.g. email), the need for additional explicit system-based knowledge storage and retrieval mechanisms could be limited. Notwithstanding the codified nature of exchanges, the virtual context creates a particularly interesting context for knowledge storage and retrieval processes which leads to additional investigations: the knowledge storage process is highly dependent on the trust, motivation and shared background of the participants (Huber, 2001) which creates considerable research opportunities in the virtual team context where the emergence of trust and shared background is limited (Gibson & Gibbs, 2006). Consequently, the role of the knowledge manager is more encompassing in a virtual team context, as not only the capturing and availability of important knowledge needs to be ensured (Malhotra et al., 2001) but also an environment needs to be created that helps individuals to overcome the inherent difficulties of the virtual context. Knowledge manager have to focus on the development of a shared understanding, learning climate and coaching practices to provide the climate in which knowledge processes are taking place (Hong & Vai, 2008). Given that the knowledge storage process is even more delicate in a virtual team scenario, the changing role of the knowledge manager is of interest

to determine the particular skills and traits a knowledge manager requires to successfully facilitate the important knowledge storage process in virtual teams.

A related matter for the virtual team context is the concern over content quality in a knowledge repository. It is often reported that codified knowledge in knowledge repositories is unlikely to be appropriately referenced for later search and retrieval (Majchrzak, Rice, King, et al., 2000). One explanation might be that knowledge is highly contextual and cannot be understood properly without capturing its local context. As virtual teams are often set up as temporary arrangements encompassing members with different degree of affiliation, the development of shared and local context creates an even greater challenge. Hence, future research is advised to pay additional attention to the *factors that influence the quality of knowledge repository developed in virtual teams.*

Questions on knowledge application

Knowledge application is arguably one of the major goals for which teams are formed (Grant, 1996). Knowledge application is the end while the other three KM processes are means to achieve this end. It seems that there must be close relationships between knowledge application process and the other three KM processes. However, in the current literature only few studies explicitly integrate knowledge application and knowledge transfer processes (e.g. Haas, 2006; Majchrzak, Rice, King, et al., 2000; Malhotra et al., 2001), or compare the performance complications of multiple knowledge processes in the same study (Haas, 2006; Paul, 2006). Future research should explore *the extent to which knowledge application is related to the other three knowledge processes.*

In a virtual team context the knowledge application process has received less attention and the few existing studies compare knowledge application between virtual teams and traditional teams by focusing on the level of IT use (Archer, 1990; Chidambaram & Jones, 1993).

However, as outlined above, while technology is an important determinant of the virtual team context and an important contributor of knowledge application, there are several other aspects that create the particular and often idiosyncratic context of virtual teams. A crude comparison between virtual teams and traditional teams does not provide the appropriate perspective for determining the idiosyncratic conditions of a virtual team. Consequently, future research should start *focusing on the diversity of virtual teams, hereby comparing the effect of various levels of IT use* (e.g., basic IT such as email vs. advanced collaboration tools) *but also focusing on other context variables.*

Questions on a holistic approach to knowledge processes in virtual settings

By examining input factors and process factors identified in the extant literature, it appears that range of factors remain applicable for multiple knowledge processes. For instance, structural factors of virtual teams (e.g., degree of virtualness, degree and types of information technologies, leadership behaviors) are identified as important factors to multiple knowledge processes. Similarly, factors such as transactive memory, shared understanding, and collective mind appear to be equally important to multiple knowledge processes. This leads us to a reasonable speculation that these factors may in fact influence the effectiveness of all knowledge processes. While it is worthwhile to test how these factors play a role in the knowledge processes that have been covered, a more pertinent question remains: *whether and how do these structural and process factors of virtual teams differ in their effects on different knowledge processes*?

Opportunities for multi-level research

The organizational learning literature has pointed out that learning is a multi-level process composed of diverse knowledge processes, such as individual learning through intuition and interpretation and collective learning through shared interpretation and joint knowledge

integration (Crossan et al., 1999). Kang (2010) elaborated on the dependency between individual and group-based knowledge transfer processes in non-virtual environments. Virtual team research has also begun to examine knowledge processes in a more holistic, less separated fashion. For instance, through an inductive study of multiple dispersed teams, Sole and Edmondson (2002) identified that bridging knowledge gaps in virtual teams requires both individual knowledge creation and collective knowledge integration. Griffith et al (1999) suggest that, to leverage potential knowledge held by team members, individuals must establish absorptive capacity and communities of practice, and the entire team must develop synergy and transactive memory to integrate the existing knowledge and point members directly to the critical knowledge resources. The multi-level process of knowledge creation has particular implications for virtual teams as team members face more challenges in creating synergies and shared interpretation. To which extent team-level and individual-level knowledge creation is synchronized and how these processes contribute to organizational benefits has been theoretically described but little empirical work has been conducted for the virtual team context. Hence, future research should investigate *how knowledge processes at the team level have individual and firm level performance implications*.

Overall, most studies reviewed here understand virtual teams as a stable and discrete entity (e.g. Robert et al., 2008). However, recent developments in virtual collaboration and work practice (e.g. web 2.0, open source) suggest that the notion of the virtual team will need to be revised as memberships in these teams are often highly transient. Ratcheva (2009) has started to extend the notion of the virtual team by highlighting the diverse forms of memberships and team affiliations but more work is required to explore the effects these transient arrangements have on the knowledge processes within virtual teams. The emergent technologies not only blur the virtual team boundaries but are likely to have implications for the virtual team's diverse knowledge processes. Research so far has focused on email and decision support

systems (Alavi et al., 2002) to determine the technology impact on knowledge creation in virtual teams. However, today's wiki technology and its collaborative editing feature, for example, provide completely new knowledge creation opportunities (Wagner & Schroeder, 2010). To remain current, virtual team research needs to consider the *implications of these new technological affordances and investigate how the changing boundaries and practices impact on the knowledge processes in virtual teams.*

7. LIMITATIONS AND CONCLUSION

In this paper, our aim was to investigate the current state of research on knowledge processes in virtual teams and to identify the factors that influence the effectiveness of these knowledge processes. Our literature search has identified 33 relevant papers that were systematically analyzed to highlight their contributions to research and to establish a comprehensive overview of the existing literature on this topic. By drawing on an established framework (Alavi & Leidner, 2001, knowledge processes, input/process/output) we were able to categorize the influencing factors but also integrate the diverse research findings and contributions of the diverse studies identified. We hope that our categorization will guide future studies on knowledge processes in virtual teams and will help to position future research. Our study has further identified and presented a range of gaps in the current state of research. The research gaps were identified based on the theoretical insights provided by the literature and we hope that the identification of the research gaps will help to guide future virtual team research.

In addition to providing a comprehensive review of the literature and identifying research gaps, our study contributes to illustrating the ongoing relevance of virtual team research for management practice. The last decade of virtual team research has contributed a large number of theoretical insights often in the form of rigorously established relationships between

individual aspects of the virtual team context. However, management practice often needs to not just consider individual effects but the range of influences as the basis for careful decision making. Hence, especially our call for research on the cumulative and opposing effects that different factors have on the knowledge processes are crucial for allowing managers to use the existing research base. Only by carefully considering the range of effects can the desired managerial impact be ensured.

Notwithstanding the theoretical and practical implications our study has several limitations. First, by seeking to provide comprehensiveness our review could only provide limited insights from the diverse literature sources analyzed to understand the individual knowledge processes. Second, every framework and model highlights particular aspects over others. We followed Alavi and Leidner's (2001) framework to contribute to the cumulative tradition of knowledge process research and provide the opportunity to integrate our findings with the extent IS research. An inductive method for analyzing the literature on knowledge processes in virtual teams would constitute a very valuable alternative approach that would likely create additional insights and would allow to compare and corroborate our current findings. Third, the literature base could be expanded to include virtual team research articles beyond the business discipline. With the qualitative analysis being our main direction and the display of the areas of research our main focus, our method and corpus is not suitable for a quantitative analysis. Fourth, as our study synthesizes investigations that adopt different methodologies, theories and variables the properties of the identified relationships are not directly comparable and the development of an integrative model is more difficult than for research domains where studies adopt a coherent theoretical position (e.g. King, 2006). By categorizing the core factors impacting on particular knowledge processes, our study aids future research that seeks to quantitatively explore individual relationships and consolidate

equivocal findings. Our study provides the basis for these and further investigations on knowledge processes in virtual teams.

A substantial body of studies has been carried on virtual teams as well as on knowledge processes as both topics in its own right remain of considerable interest to research and practice. However, the paradox of virtual teams requires a focus on the intersection of these two research areas: virtual teams are largely established to join disparate knowledge resources while, at the same time, it is the virtualness of the teams that creates the barriers to knowledge processes. As we can observe a continuous increase in the virtualisation of work practices this particular research focus is likely to become of even greater relevance. We believe that our work has the potential to help to rapidly fill the gaps in our understanding of knowledge issues in virtual teams and help move forward research and practice in the field.

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Appendix I – Articles Included in the Review

Authors	Topic	KM process	Technology	Task	Theory	Method	Subjects	Time Frame
Alavi, M. 1994.	Cognitive learning Cognitive load of learning process	Knowledge creation	Email vs. GDSS	Develop thorough understanding of a customer-oriented program	Social learning theory	Experiment – control variable different level of GDSS	4 50-member groups of EMBAs	10-week distance learning
Alavi, M., G.M. Marakas, Y. Yoo. 2002	TML, including IT-enabled collaborative learning	Knowledge creation	N/A	N/A	TML theories	N/A	N/A	N/A
Alavi, M., Tiwana A. 2002.	Challenges to Knowledge application by VTs	Knowledge application	N/A	N/A	Communication theory	N/A	N/A	N/A
Archer, N.P. 1990.	Knowledge generation: Decision quality, # alternatives	Knowledge application	computer conferencing	Decision making	AST	Experiment	4-5 member teams, students	8 week
Baba, M.L., Gluesing, J., Ratner, H., Wagner, K.H. 2004	Cognition convergence	Knowledge transfer	Videoconferencing Electronic meeting system Knowledge repository	Customer relationship management	Shared cognition	Ethnography	1 global virtual team	14 months
Behrend, D., Erwee, R. 2009	Social network	Knowledge transfer	N/A	N/A	Social network theory	Case study, survey method	6 virtual teams	N/A
Boutellier, E.A. 1998	R&D as knowledge production	Knowledge application	Various technologies	Commercial software development	N/A	Case study	N/A	N/A
Capece, G. Costa, R. 2009	Team structural configuration	Knowledge creation	Various technologies	Website development	Social network theory	Social Network Analysis	4 6-member teams	7 weeks
Chang K.T. 2008	Influence of psychological contracts on knowledge sharing	knowledge transfer	N/A	36 Software development teams which are part of one R&D unit	Psychological contract theory	Survey	252 members	N/A

Cramton, C. 2001.	Structural antecedents, and consequences of Mutual knowledge/mutual understanding	Knowledge transfer	Email, other communication tools	Developing a business plan and prepare for presentation	Communication lit, Attribution theory, the concept of cognitive load and feedback dynamics	Analysis of 1649 emails printouts of their online chats tem logs of their use of communication tool 26 analysis papers grades	13 6-member teams, all graduate students in the U.S.	7 weeks
Gibson, C.B., Gibbs, J.L. 2006	Team structure and innovation	Knowledge application	Email, Teleconference Text exchange	Aerospace design	Psychological safety	Case study + survey	14 teams + 56 teams	N/A
Griffith, T.L., and M.A. Neale. 2001.	Transactive memory	Knowledge transfer	ICT	N/A	Theory of transactive memory	N/A, Theory paper	N/A	N/A
Griffith, T.L., Sawyer, J.E., Neale, M.A.. 2003.	Knowledge transfer and knowledge acquisition in more or less virtual teams	Knowledge transfer	ICT, Collaborative technology	N/A	Communication theory	N/A	N/A	N/A
Haas, M.R. 2006	Cosmopolitan versus local membership, knowledge, and performance	Knowledge creation /application	Email, teleconferencing, telephone	International development	International management	Survey	96 international virtual teams	N/A
Kim Y., Jarvenpaa S. L. 2008	Effect of boundary spanning mechanism on knowledge transfer	Knowledge transfer	Diverse information technology	R&D projects	N/A	longitudinal case study	30 individuals within 8 manufact.g groups and 2 admin. groups	One year
Krumpel, K. 2000	Group knowledge generation, the effect of leader	Knowledge application	Email	Technology standardization	Structuration theory CMC literature	Case study	working group, 51 members	Ongoing
Majchrzak, A., Rice, R.E., Malhotra A., King N., Ba S.. 2000b.	Knowledge sharing, innovative decision making	Knowledge transfer Knowledge application	Collaborative technology	Creating a highly innovative product	AST	Case study – weekly virtual meetings, electronic log files, interviews and weekly questionnaires	1 8-member team	10 months (15% time commitment)

Majchrzak, A., Rice, R.E., Malhotra A., King N., Ba S... 2000a.	Knowledge sharing/commonality	Knowledge transfer	Collaborative technology	Creating a highly innovative product	Media richness,Social presenceTask circumflex	Multi-method longitudinal research study	1 eight- member team	10 months (15% time commitment)
Majchrzak, A. Malhotra, A. John, R. 2005	IT support and knowledge acquisition	Knowledge creation	Lotus Notes, Groove, Netmeeting, E-Room	A variety of tasks	Cognitive – affective model of communication	Survey	54 teams	N/A
Malhotra, A., Majchrzak A., R. Carman, and V. Lott. 2001.	Knowledge sharing within VTs facing highly innovative goals	Knowledge transfer Knowledge storage and retrieval	Collaborative technology	Highly innovation – Product development problem	N/A	Case study	1 eight-member team	10 months (15% time commitment)
Malhotra, A., Majchrzak, A. 2004	Leverage globally dispersed knowledge resources	Knowledge application	Multiple technologies, such as email, collaborative technology, teleconferencing	Creating a highly innovative product	N/A	Case study / survey	55 virtual teams	N/A
Ocker, R.J., and G.J. Yaverbaum. 1999	The effectiveness of learning using computer-mediated technology	Knowledge creation	Asynchronous computer conferencing tech	Business case analysis	Computer-mediated communication in education	Repeated-measure experiment	10 groups of 43 MBA students	two weeks
Paul 2006	KM processes in virtual settings	Knowledge creation/ transfer	Videoconference Multimedia	Teleradiology Distance learning teleconsultation	Grounded theory	Case study	10 virtual teams	N/A
Qureshi, S., and D. Vogel.2001	Learning, Adaptation(technology, work, social), structure, specialization, coordination	Knowledge creation	N/A	N/A	Structuration theory	N/A	N/A	N/A
Ratcheva V. 2009	Integration of multidisciplinary knowledge through boundary spanning	Knowledge transfer	N/A	Development of high tech components	N/A	longitudinal multiple case study	5 project teams	6 months
Robert, L.P., Dennis A.R., Ahuja, M.K., 2008	The impact of social capital on knowledge sharing/application and decision quality	Knowledge transfer/application	Online communication environment within course management software	University admission of students	Social capital	Experiment	46 teams	2 hours experiment after 2 months of social capital building
Robey, D., Khoo H.M.,, Powers C.. 2000	Situated learning	Knowledge creation	Various technology	On-going customer-specific tasks	Theory of situated learning	Qualitative interview	22 workers and managers in three cross-functional teams	3+years

Sole, D., Applegate. L, 2000	Team knowledge sharing; Team effectiveness	Knowledge transfer	Collaborative tech in a broad sense	Solution development	Shared meaning	Field-based study Semi-structured interviews, reviews of company documents, observation and participation in project	Two development teams in a company	N/A
Sole, D., Edmondson, A.. 2002.	The effect of situated knowledge on team performance	Knowledge creation	Computer-mediated technology	Problem solving	Theory of situated learning	Qualitative field study	seven development projects, each spanning multiple sites	N/A
Staples D.S., Webster J., 2008	Effects of virtualness and task interdependence on the relationship between trust, knowledge sharing and team effectiveness	Knowledge transfer	N/A	N/A	Social Exchange theory	Survey	824 participants	N/A
Vaccaro, A., Veloso, F., Brusoni, S., 2009	Effects of ICT on knowledge creation processes	Knowledge creation	Different ICT tools, CAD, workflow, databases	R&D projects in the automotive sector.	Model of knowledge creation (SECI)	Case research	Two engineering development teams	3 weeks
Vogel, D.R., Davison, R.M. Shroff, R.H., 2001	Issues concerning virtual team learning	knowledge creation	Group Systems eRoom	Managing software projects Identify the impact of software defects	Cultural sensitive theory of sociocultural learning; GSS	Case study	7 virtual teams	Four weeks
Yoo, Y., 2001.	The effects of transactive memory and collective mind on team performance	Knowledge transfer	Text-based computer mediated-communication Web-based interfaces	Business simulation	Social-cognitive literature	Longitudinal surveys	38 virtual teams of graduate students	Eight weeks