Beyond Knowledge Transfer: A Typology of Knowledge Sharing Behavior in Virtual Teams

Deborah L. Sole[a]
Lynda M. Applegate[b]

[a] Graduate School of Education
Harvard University, United States of America
dsoule@dba2003.hbs.edu
[b] Graduate School of Business Administration
Harvard University, United States of America
lapplegate@hbs.edu

Abstract

The ability to mobilize knowledge from different parts of an organization is central to organizational success in changeable and competitive, global environments. Although there is much research on knowledge transfer in organizations, it focuses predominantly on organizational units as a level of analysis, and attends primarily to the outcomes rather than the processes of knowledge mobilization and use. We build on the more fine-grained concept of knowledge sharing focused at the interpersonal and group level of analysis, which offers a complement to studies of knowledge transfer and can yield valuable additional insights into the phenomenon of how organizational members use others' knowledge successfully for organizational ends. This study contributes a more nuanced understanding of how knowledge is mobilized in practice by empirically identifying three distinct but complementary knowledge sharing practices used by globally dispersed new product development teams. We discuss implications for group and organizational learning. (146)

Keywords: virtual teams; knowledge sharing; organizational learning; group processes;

Suggested track: Knowledge and learning issues in the context of global, virtual teams

1. Introduction

The ability to mobilize knowledge for organizational purposes is central to organizational success in changing competitive and global environments. Knowledge is an essential input in recognizing a need for change and in conceiving and implementing organizational activities that respond effectively to that need. Despite increased interest, by scholars and practitioners alike, in how organizations create, retain, and transfer knowledge, these processes remain to be fully elucidated (Argote, 1999; Argote & Ingram, 2000; Argote, Ingram, Levine, & Moreland, 2000; Huber, 1991). Moreover, we still lack insight into how these processes correspond to productive work practices as accomplished by small groups and teams—despite the prevalence of team and group structures in organizations (Edmondson, 2002). Virtual teams, particularly, are an increasingly common and essential form for accomplishing work in the 21st century (Handy, 1995; Townsend, DeMarie, & Hendrickson, 1998) and are especially favored as a means to mobilize diverse expertise and knowledge from different geographic localities (Boutellier, Gassmann, Macho, & Roux, 1998; De Meyer, 1993; Gorton & Motwani, 1996; Townsend et al., 1998). Since team members' actions and interactions have the power to critically influence an organization's ability to develop and leverage better knowledge and understanding (Edmondson, 2002; Senge, 1990), it is essential that we better understand the relationship between team practices and effective organizational knowledge processing. This study contributes to a more nuanced understanding of how knowledge is transferred in organizations through exploring the dynamics of effective knowledge sharing interactions in globally dispersed, cross-functional new product development (NPD) teams.

2. Conceptual Background

Knowledge is mobilized for use from different parts of an organization through processes of knowledge transfer or knowledge sharing, described as "learning from the experience of others" (Argote et al., 2000, p.1)

2.1 Knowledge Transfer

Knowledge or best practice transfer studies generally adopt the organizational division as a level of analysis, investigating how knowledge manifest in effective work practices or processes in one organizational division is transferred to another division (Szulanski, 2000). At this level of analysis, knowledge transfer is frequently conceptualized as a transmission from source to recipient, following Shannon and Weaver's (1949) conduit theory of communication, where functional or regional organizational divisions are identified as sources and recipients in the knowledge transfer process (e.g. Argote & Ingram, 2000; Argote et al., 2000; Darr, Argote, & Epple, 1995; Kogut & Zander, 1992; Szulanski, 1996; Szulanski, 2000; Zander & Kogut, 1995). Examples include examination of technology transfer from R&D to manufacturing divisions (Leonard-Barton, 1995), the transfer of capabilities or "best practices" between similar functions in different organizational locations (Darr et al., 1995; Szulanski, 1996; Zander & Kogut, 1995), and the acquisition of production expertise transferred from shift to shift on a manufacturing line (Epple, Argote, & Murphy, 1996). Knowledge flows are difficult to isolate and track at this level of analysis however, therefore, empirically, these studies often focus on *outcomes* rather than *processes*. An important exception is the work of Szulanski (2000) where different stages of the transfer process are identified and associated with different sources of transfer difficulty.

Studies that rely empirically on outcome variables assume that knowledge has transferred successfully if positive changes in performance are manifest in the receiving organizational units (e.g. Argote, Beckman, & Epple, 1990; Darr et al., 1995). For example, in a study of pizza stores, Darr and colleagues found that the unit cost of production declined significantly at individual pizza stores owned by a single franchisee, as they collectively gained experience in production. Nevertheless, this account lacks process detail about how production knowledge passed among the franchised stores. In many cases, knowledge or best practice transfer is also framed as occurring separately from or prior to ongoing productive work. Thus, when specific activities or behaviors are documented, they are largely considered relevant only for special occasions.

2.2 Knowledge Sharing

Other studies of how knowledge is mobilized to or from particular parts of the organization focus on team contexts where members must exchange and combine knowledge to achieve their joint work goals. Studies focused at the group and interpersonal level tend to use the terminology of "knowledge sharing," defined as the *provision or receipt* of task information, know-how, know-who, or feedback (Cummings, 2004; Hansen, 1999). In a group setting, knowledge sharing is conceptualized as entailing bidirectional flows of knowledge, both from the group outwards to the greater organization and from outside back into the group. Sharing knowledge beyond the group is shown to be valuable to performance (Ancona & Caldwell, 1992; Faraj & Sproull, 2000), particularly when group members are "structurally diverse;" that is, they represent different functions, regions or business units (Cummings, 2004). Knowledge sharing among members within the group is also related to group performance (Faraj & Sproull, 2000). Clearly, sharing knowledge at the team level is valuable behavior, yet evidence suggests that, for a variety of reasons, knowledge sharing efforts in both co-located and virtual teams are often ineffective (Bechky, 2003; Cramton, 2001; Dougherty, 1992; Lam, 1997).

First, differences among participants' domains of expertise can engender misunderstandings, as a result of different terminology, different priorities and different criteria for performance (Bechky, 2003; Dougherty, 1992). Study of organizational knowledge creation suggests that effective knowledge exchanges depend on the existence of some common background knowledge (Nonaka, 1994) among communicants that enables knowledge sources to frame their knowledge in accessible terms and enables recipients to make sense of the knowledge so imparted. Similarly, research on technology transfer suggests that absorptive capacity—the ability to comprehend newly acquired information—depends heavily on the existence of prior complementary knowledge bases (Cohen & Levinthal, 1990; Szulanski, 1996). Since virtual teams often are assembled precisely with a view to engaging diverse expertise, misunderstandings are likely to be more prevalent. Dougherty's (1992) findings suggest that, when diverse domains of knowledge are involved, effective knowledge sharing requires a particular kind of highly interactive engagement. Yet it remains an open question as to whether such interactive behavior, viable in co-located teams, is also feasible in geographically dispersed settings or whether, alternatively, virtual teams need to develop sharing practices specific to their virtual setting.

Further, virtual team studies, particularly, frequently highlight the difficulties associated with knowledge-based interaction, or communication in general, owing to informational constraints imposed as a result of team members' geographical separation (e.g. Cramton, 2001; Lam, 1997; Straus & Olivera, 2000). For instance, the extent to which dispersed team members establish what "mutual knowledge" (Krauss & Fussell, 1990) they already hold in common is likely to affect their ability to learn from each other (Cramton, 2001). In addition, technological and logistical constraints imposed by team members' geographical separation can limit informal spontaneous interaction, thereby inhibiting the development of trusting relationships within which knowledge sharing is possible and likely (Straus & Olivera, 2000).

In sum, these findings suggest that it is not enough merely to have access to relevant knowledge; in addition, it must also be understood and effectively engaged in order to be useful to the team (or other organizational unit), and ultimately the organization. Although some virtual teams do successfully integrate their collective knowledge to achieve team tasks (Jarvenpaa & Leidner, 1999; Maznevski & Chudoba, 2000), we lack accounts of exactly *how* globally dispersed, occupationally diverse group members engage with each other or with outsiders to provide or receive knowledge that is meaningfully understood and effectively applied. Thus, although the relationship between knowledge transfer or knowledge sharing and performance is strong, we still know relatively little about the nature of effective knowledge sharing interactions.

2.4 Study Aims

This study was guided by prior work suggesting that the adoption of an interpersonal or group level of analysis, a focus on the context of productive work, and attention to practice might yield a more nuanced understanding of how and when organizational members really *do* learn from the experience of others. In this study, knowledge sharing is conceptualized as a process in which participants interact with each other to exchange knowledge or information, through which team members gain new, actionable insight into project tasks and issues for which solutions were not previously obvious — i.e. they learn (cf. Edmondson, 1999). Such interaction can be direct or technology-mediated in time and/or space. Effective knowledge sharing behavior results in team members actually using this new insight obtained through others to take effective task-related action, and thus will be related to both team learning outcomes and, ultimately, team performance.

Geographically dispersed new product development (NPD) teams were chosen as a research sample because the non-routine, learning-rich nature of their task offered a high-intensity context for studying knowledge sharing interactions. Furthermore, due to the presence of team representatives from different disciplines and occupations, knowledge sharing difficulties were expected to be particularly salient.

3. Methods and Data

The study objective of exploring a process suggested qualitative, longitudinal case study research, which offered the opportunity to investigate (1) unstructured interactive behavior, and participants' perceptions of that behavior, (2) in contemporary settings (3) where the context was believed to be important for understanding existing and emergent behaviors (cf. Yin, 1994, p.13). Data was collected using an embedded multiple case design (Eisenhardt, 1989; Yin, 1994), which investigated multiple "learning episodes" occurring in the natural course of work of seven geographically dispersed new product/process development teams. One level of analysis focused on the virtual development team and its work on a particular development project. Each team was studied retrospectively and in real-time over a series of months, enabling the development of an account of typical team processes. Cases encompassed data on team composition and physical distribution, history and status of the project, project complexity, origins of key product and process knowledge for the project, team technology use and patterns of interaction, and overall team and project performance. Embedded within each project-team case were multiple learning episodes, each a longitudinal account of team behaviors and activities that had moved the team from a problem or “knowledge gap” to a state in which they possessed new insight to address that gap.

3.1 Research Site and Sample

The research site was a multinational manufacturing company designing and producing polymer film products for use in industrial and consumer applications. The company employed over 4000 people worldwide and company revenues exceeded $1 billion per year. Formed as the result of an earlier acquisition and a subsequent joint venture, the company relied heavily on teams staffed from different research centers, production sites, and commercial offices around the world for new product and process development. Development projects were selected from a single organization in order to constrain extraneous variation at the industry and environmental level (Eisenhardt, 1989), but retain sufficient variance in terms of different contextual settings.

Project teams for this study were selected theoretically for the opportunities they offered to observe variance in those variables that the literature suggested as being important to the teams’ behavior (Glaser & Strauss, 1967; Yin, 1994). Teams were added to the study in phases, allowing for progressive refinement of the conceptual model and supported the logic of replication. All teams had cross-functional representation, highlighted as a key characteristic in the product development literature (Brown & Eisenhardt, 1995), but they varied in project complexity, creating different implications for interdisciplinary collaboration. All teams were geographically dispersed but differed in the extent of their geographical distribution—for example, some teams included members in Asia, America and Europe, while others spanned only European locations—and thus in the ease with which they might occasionally meet face to face. All teams were engaged in ongoing development, which accommodated a longitudinal orientation and exploration of work practices that emerge over time. Team members had a variety of information and communication tools—such as telephone, teleconferencing, voicemail, email, shared electronic workspaces—that enabled them to interact virtually in between the occasional face-to-face meetings (see Table 1).

3.2 Data Collection and Sources

We collected data primarily through seventy semi-structured in-depth interviews conducted with (1) core team members, (2) peripheral participants, and (3) management associated with the development projects, drawn from seven sites engaged in development activities. Informants represented research and development, engineering, technical services, customer service, marketing, sales, and manufacturing. Informants were told that the study was concerned with understanding the experience of dispersed knowledge sharing, particularly in non-routine work situations where the need to share knowledge effectively was paramount. The interview protocol was designed to elicit information about the nature of development activities and objectives, types of knowledge drawn upon during these activities, the nature of knowledge-intensive interactions, the use of different technologies in knowledge exchanges, and norms of behavior at the site. Interviews with management focused on the teams' performance and project progress. Interviews with core and peripheral team members incorporated an adaptation of the critical incident technique (CIT) (Flanagan, 1954) to elicit details of significant learning episodes during the project's history. Participants were requested to describe particular incidents or episodes that they considered significant learning events that had occurred over the course of the dispersed development. The CIT, "essentially a procedure for gathering certain important facts concerning behavior in defined situations" (Flanagan, 1954, p. 335), was considered appropriate for examining dispersed team work practices because it offered a way to learn about specific behaviors and responses in settings that were complex and involved a high degree of uniqueness in work approaches.

Interview data was supplemented by real-time access to the organization's shared electronic repositories of project documentation during the twelve months of the study. These included minutes of team meetings, project reports and presentations, and feedback from project tasks such as customer visits, analytical evaluations, and manufacturing trials. Since these documents were prepared by project participants in real time, they provided an effective means to cross-check informants' retrospective reports and observed behaviors. The first author also spent approximately two months in the field observing some of the teams in action, and gaining first-hand experience of different organizational settings. Observations of both virtual and physical team member interactions, such as planned face-to-face meetings, teleconferences, casual encounters and conversations, visits to pilot and production facilities, and practical activities such as running experiments, provided further insight into how virtual team members learned about the needs of their project and approached particular tasks.

Table 1 Development Projects and Teams

Project Team	Development Task	Task Complexity [a]	Core Team Composition	# of Sites Involved [b]	# of Countries
GROSSO	Develop new product for high-margin market segment using new product and process technology	High	• Research Scientist* • Experimental Scientist • Process Development Engineer • Materials Specialist • Production Engineer • Global Market Manager	4 (+3) SiteC SiteD SiteV SiteW	5
BIANCO	Develop new product for strategic new customer using combination of existing product and process technologies	Medium-High	• Product Development Engineer* • Process Team Leader • Technical Specialist • Research Scientist • Global Market Manager (US) • Regional Market Manager (JP) • Regional Commercial Manager (JP)	5 (+2) SiteB SiteH SiteI SiteT SiteW	3
CHIARO	Develop replacement products for existing profitable market through novel process technology	Medium-High	• Production Development Engineer* • Market Development Manager • Experimental Scientist • Process Design Engineer • Production Supervisor • Market Manager (Europe)	3 (+1) SiteD SiteS SiteW	2
GRIGIO	Develop new product for existing customer, using combination of existing process technology	Medium	• Product Development Engineer* • Research Scientist • Research Technician • Process Team Leader • Technical Service Representative • Sales Account Manager	3 (+2) SiteH SiteW SiteX	2
SCURO	Develop replacement products for existing market using combination of existing process technology	Medium	• Production Engineer* • Production Engineer • Process Technician • Technical Service Representative • Sales Account Manager	3 (+3) SiteC SiteH SiteX	2
ROBUSTO	Develop improved process technology for platform production process	Medium	• Research Engineer Specialist* • Process Specialist • Materials Specialist • Production Engineer • Production Technician • Maintenance Engineer	3 SiteC SiteH SiteW	2
NERO	Develop replacement product for important customer, using existing process technology	Low	• Applications Development Manager* • Experimental Scientist • Production Engineer • Sales Account Manager	3 (+1) SiteH SiteW SiteX	2

* Project team leader (PTL)
a Calculated from internal project evaluation criteria;
b Number in brackets indicate critical interaction with customers and / or suppliers.

This triangulation of various sources and different data collection techniques provided multiple perspectives on team learning and sharing issues, and allowed for cross-checking of existing and emerging concepts (Eisenhardt, 1989; Glaser & Strauss, 1967; Pettigrew, 1990).

3.3 Data Analysis

Data collection, coding and analysis proceeded in an iterative fashion (Eisenhardt, 1989; Glaser & Strauss, 1967), with earlier stages of the research being more exploratory and open-ended, and latter stages being guided by the concepts identified in preliminary analyses. The objectives were to identify episodes of learning in dispersed teams, examine the significance, form and consequences of knowledge-intensive interactions that led up to team learning outcomes, and look for patterns in such behavior. We analyzed data within each team as well as across teams, using qualitative techniques to analyze the data (Eisenhardt, 1989; Miles & Huberman, 1984).

We first focused generally on interview transcripts, observation notes, and electronic documentation to identify data suggestive of knowledge sharing (such as reference to the skills, expertise or experience of oneself or other individuals) and data pertinent to learning outcomes (such as a shift in cognitive understanding and subsequently changed behavior). Later, we focused more specifically on the significant learning episodes that were identified from the collective input from multiple team informants, from firsthand observations and through corroborations against online records. We sought to refine our understanding of the learning and knowledge sharing behaviors identified, by looking for common and contrasting dimensions (such as participation and styles) of those behaviors. This level of attention yielded prominent dimensions of knowledge sharing behavior as emergent categories from which three meaningful knowledge sharing practices emerged.

Subsequently, a renewed focus on the narrative aspect of each episode revealed how a sequence of sharing practices, used in combination over time, ultimately led to the learning outcome described by the informants. The recognition that dispersed team members selectively enacted a sharing response, according to the knowledge gap as they perceived it, prompted the conceptual notion of a *repertoire* of sharing practices.

4. Findings

Sharing knowledge and learning are integral to the work of teams involved in non-routine activities such as new product development. Team members must repeatedly develop and apply their individual and combined skills and expertise to address unique problems encountered in the course of each development initiative, and integrate the new insights so acquired. In this section, we first describe and contrast the different knowledge sharing practices identified in the virtual teams studied. Subsequently, we describe how these sharing practices act as a repertoire of complementary behaviors, thus collectively accomplishing effective knowledge sharing under various and changing circumstances.

4.1 Types of Knowledge Sharing Practices in Virtual Teams

In the analysis of the data, prominent dimensions emerged as categories for describing knowledge sharing behavior occurring in virtual team settings. These dimensions clustered into a subset of dimensions that describe the knowledge shared and a subset of dimensions that describe the nature of participants' interactions. The resulting empirical combinations of these descriptive dimensions yielded a typology of three knowledge sharing practices, exhibiting variation in the configuration and engagement of knowledge by virtual team participants and in the associated team learning outcomes (see Table 2 and Table 3 for examples):

- Contribution - unilateral action to disseminate codified, specialist knowledge within a shared frame of reference;
- Coaching - bilateral, iterative interaction to dispense discursively-available, specialist knowledge after clarifying the frames of reference; and
- Collaboration - multilateral, iterative interaction resulting in discovery of new knowledge through generating shared frames of reference.

Type I Contribution: Disseminating individual Insight. Knowledge sharing as *Contribution* involves the articulation of an individual's experience, understanding or insight with respect to a project issue, in a way that makes that insight accessible and useful to other members. Although team members studied here did not use the term "contribution" in referring to their behavior, they were intentional in their attempts to contribute or convey their insights or observations to others. They sought to propagate their own understanding among their colleagues, creating, in this way, an opportunity for others to build sequentially on that understanding.

Contribution is characterized by a predominant role for a single "specialist" individual in the team whose knowledge and expertise is central to the interaction and who unilaterally initiates the interaction. Team members acquire "specialist" or "expert" status by virtue of their discipline or their occupation, their particular current role in the team, or simply due to the relevance of their experiences. Contribution involves sharing individual experience or insight regarding an existing, common concern to the team, and thus assumes a sufficient existing basis of shared understanding by the team members with whom the specialist was interacting. The practice *per se* lacks opportunity for feedback, and thus was most effective when it was used in the context of an established topic of shared concern and built on a shared frame of reference.

Table 2 A Typology of Knowledge Sharing Practices in Virtual Teams

	CONTRIBUTION	**COACHING**	**COLLABORATION**
Dimensions of Knowledge			
Locus of relevant knowledge	Single "specialist' by virtue of role or discipline	Single "specialist' by virtue of role or discipline	Multiple participants with diverse roles and overlapping disciplines
Form of relevant knowledge	Codified or readily articulated Know-that, know-why	Partially codified but discursively available Know-how, know-that	Partially- or un-codified but discursively available Know-how, know-why
Critical knowledge flows	'Specialist' • Team members	'Specialist' • Team members (core & peripheral)	Team members ⇔ Team members (core & peripheral)
Dimensions of Interaction			
Participants	'Specialist' member; other team members	'Specialist' colleague or member; other team members	Team members and others with respective specializations
Degree of interaction	Simple, bounded. Communicative action assumes sufficient shared frames of reference (e.g. pertaining to a known project activity).	More complex, iterative. Discursive action seeks to clarify/ generate shared frame of reference (e.g. around a project-relevant topic).	Complex, multilateral, iterative. Highly discursive action aims to generate shared frames of reference (e.g. regarding an open project issue).
Direction and initiation of interaction	Primarily unilateral. Initiated by the specialist individual.	Bilateral between "specialist' and "knowledge seeker/s'. Initiated by either party.	Multilateral, centered on the group of team members and other colleagues. Initiated by any party.
Timing of interaction	Tended to occur when a team member reached (temporary) *individual closure on ideas* or activities: signaled by statements: "I believe that..."; "I've decided..."l "I found…"	Tended to occur when team members sought *clarification of ideas or experiences.*	Tended to occur when team members sought *alternatives, different answers, or confirmation/refutation of answers they'd already uncovered*, or confrontation/ refutation of their expectations.
Form and technology medium	Mostly written – documents. Email, document attachments, documents in shared electronic repositories, etc.	Mostly (or initially) oral — dialogue, conversations. Telephone calls, email, FtF.	Mostly oral and active — discussion, joint activity. Telephone calls, teleconference calls, videoconference calls, desktop-conferencing, FtF discussions.
Learning Outcomes			
Primary value (near-term effect)	Sequential replication of project-relevant insight from specialist to other members of the team.	Sequential adaptation of project-relevant insight from specialist to other members of the team	Synchronized discovery of project-relevant insight by project participants
Secondary value (intermediate term effect)	Development of intellectual capital through expansion of organization's encoded knowledge	Development of human and social capital through expansion of social networks and interpersonal trust	Development of social capital through expansion of social networks and interpersonal trust

Table 3 Examples of Knowledge Sharing Practices in Virtual Teams

	Contribution: Disseminating individual insight *(or not)*	**Coaching: Dispensing individual insight *(or not)***	**Collaboration: Discovering collective insight *(or not)***
Markers	Interaction grounded in individual effort: Individuals offering analyses and conclusions; explicating reasoning and understanding *(or the opposite: individuals withholding information, not sharing analyses; not explaining when explanation is expected etc.)*	Interaction grounded in bilateral effort targeted to specific needs of known recipients: Individuals volunteering information, providing advice, resources, and assistance tailored to specific needs *(or the opposite: individuals withholding feedback or assistance, not explaining sufficiently, etc.)*	Interaction centered around collective effort: Groups involving different perspectives; making intentional efforts to integrate and account for differences of perspective or approach, etc. *(or the opposite: groups not involving different perspectives; making little effort to acknowledge differences, etc.)*
		Illustrative Data	
Presence of knowledge sharing	The first trial here didn't work – the rationale was that we hadn't controlled the [condition of the material] sufficiently, hence [we undertook] the drying tests. The second trial also didn't work but we're 99% certain that the polymer was dry enough. There was a recent note from [the Team Leader] explaining the rationale. (GROSSO, interview with Experimental Scientist) For example, [the technical specialist] is very good about documenting his visits to the customer. That helps our communication a lot – we see his English version of what the [Japanese] customer thought, and we can ask questions based on that. (BIANCO, interview with Product Development Engineer) Polymer chemist excitedly emails colleagues "Chaps! A light bulb has just gone on in my head...." Shares insights regarding chemical properties of the team's chosen polymer, and explains why an alternative material might be suitable (CHIARO, email from Experimental scientist)	I've suggested some things when I finally figured out, "Oh, that's why they're struggling – because they've never been taught how to do new product development." I've tried to start suggesting things rather than just imposing it on them saying, "You have to follow this.' I try to approach it from, "have you thought about this, considered this, this and this." (SCURO, interview with Technical Service Representative) I put together a history or a narrative of [a related development program of] product and process chemistry for the Team Leader, to bring him up to speed on our technology [at this site] (GROSSO, interview with Polymer Specialist) Facing unexpected performance problems, the GROSSO team consulted onsite colleagues who were "experts' on the chemical behavior of particular product components to confirm their hypotheses and decide how to proceed. As a result of the meeting, the team initiated a new plan of experimental action to verify the theoretical explanation offered by the experts. (GROSSO3, observation)	The engineer and the technician make a good team because the engineer tends to be the more cerebral one and the technician is the more practical one and usually together they reach pretty good solutions on how to implement projects and changes…. Engineers are often times known for putting in things that look great on paper, but may not be quite practical out on the line… And by discussing back and forth, you could come up with something. Technicians keep engineers out of trouble. (ROBUSTO, interview with Production Engineer) That's one of the stipulations [the customer] wanted; they wanted [this particular property]. Now through talking to [the Team leader] and several other people with a lot more knowledge than myself, we tried several new […] additives. It's built on the knowledge that everyone had (NERO, interview with Experimental Scientist) We met at [the manufacturing site] with the site engineers to identify which [production] unit we could use for a [new production technique]. We were asking questions like: would the additional equipment fit, where could we get power for it, etc? We came away with the result: "Yes, we can do this!' (CHIARO, interview with Market Development manager)
Absence of knowledge sharing	*I found out from [the chemist] that [the production members] had gone for a different heater – with a different heating temperature range than the one I'd thought of. Nobody [from production] has communicated that to me. Now as I'm the lead contact with the company making it, it seems a bit of an omission not to tell me that they've made that change. (CHIARO, interview with Design Engineer)*		*They have local team meetings, like up in [the manufacturing site], that I don't always know about. …I've asked to be invited, but I'm not invited. And their explanation is— I don't know, I guess they see it as more an internal manufacturing issue—they don't know that I need to be involved with those types of decisions…. (SCURO, interview with Technical Representative)*

Contributed knowledge tends to be codified in the sense that it can be symbolically represented in words, models, and diagrams, and, in this study, was most often shared in a durable form through written channels such as email (messages or attachments) or shared file repositories. For example, when the experimental scientists in GROSSO, GRIGIO, NERO, and BIANCO conducted practical experiments or tests on their own, they forwarded their results, analyses and conclusions to the rest of the team. These usually took the form of a document attached to an email message, but in some teams, especially GROSSO and GRIGIO, the full analyses were made available in the shared project repository as well. Similarly, sales and customer liaison members disseminated detailed reports and interpretations of their customer visits so that other team members could develop an understanding of product expectations in the market and understand the constraints or nuances of a customer's downstream process.

The timing of Contributions is determined by the individual, rather than by the team, as the behavior is triggered by the individual member's achievement of new personal understanding about an issue as a result of his or her independent task activity and/or reflection. Such new individual insight could emerge in different ways. New individual understanding was often derived from individual experiences in which the team, as a whole, could not or did not participate—such as interacting with the customer. Those team members who interacted directly with customer representatives gleaned insight into the customer's perspective—such as awareness of their production capabilities and limitations, or an understanding of exactly how they evaluated a product—through multiple conversations with customer representatives and through visits to their sites. Most dispersed team members did not have direct contact with the customers for whom they were developing products. Yet, as the market development manager of CHIARO explained, "being on the spot" and "having a finger on the pulse" was critical to the success of the product development and market introduction. Thus the shared insights from customer contact members were essential for the dispersed team to incorporate this understanding into their product design decisions. BIANCO's team leader, who had never met their client on the other side of the world, explained how this worked in his team:

> [The Technical Specialist in Japan] is very good about documenting his visits to the customer. That helps our communication a lot – we see his English version of what the customer thought, and we can ask questions based on that.

Commenting that “the status changes day by day,” that technical specialist described how he drew on his close personal relationships with customer representatives, visiting them many times per week and telephoning them frequently, to act as “a broker” of information between the dispersed team and the client.

Sometimes new personal insight resulted from independent reflection that followed group interactions. For instance, the CHIARO team had found that using the original polymer in their new production technique led to product handling problems during manufacturing. The technical and production members had discussed how they might resolve this issue but without reaching any conclusions. Some time later, the polymer chemist suddenly recognized a relationship between certain chemical properties of the polymer and the effects they had observed in the manufacturing process. This sense of sudden personal clarity was evident in his words as he emailed his colleagues: “Chaps, a light bulb has just been turned on over my head! …..” He went on to explain his insights regarding the chemical properties of the team’s chosen polymer, and elaborated on why an alternative material could be suitable. In a separate interview, the Market development manager referred to this possible choice of alternative material and elaborated on actions they had taken to procure and test it.

To effectively share what they had discovered individually, team members needed to do more than just communicate the outcomes of their efforts, such as the results of an experiment or test. They also *interpreted* that outcome in the light of project objectives so that others would not need specialized knowledge of the activity in order to understand the implications of its outcome. In GROSSO, for example, various members, most notably the research scientist and process engineer, periodically compiled focused reports summarizing the learning derived from preceding technical discussions or from a sequence of experimental work, thus further making explicit the conclusions drawn from these practical activities. Other team members demonstrated an understanding of the report conclusions and implications, referring to these in their conversations and interviews.

Contribution was found to be mostly unsolicited, but in established and effective teams it became an expected part of an individual’s role, and was subsequently incorporated into the way the team learned. In GROSSO, since so much of what the team had discovered was documented electronically and centrally available, team members started to use this electronic source of team knowledge directly in the course of their work (cf. Orlikowski, 1996). In one example, during an absence of the team's process engineer, the scientists on the team were observed as they consulted the online records as a "memory-refresher" in order to draw on the absent engineer's processing guidelines in planning a new trial. Moreover, as individuals contributed new documents, these were linked to existing reports and discussion documents. In this way the team built, electronically, its memory of what it knew.

In terms of its direct effects on learning, effective Contribution practices enables other team members to *replicate* one member's insight into a particular issue. Since team members were not co-located they lacked opportunities to observe what other members were busy with, and thus relied on receiving explicit notification of conclusions, decisions and actions. Contribution thus had the effect of raising the general awareness of team members regarding all the multiple activity strands that were concurrently underway. As a scientist on the GROSSO team put it,

> To me, whether you're working directly on something, or you just have a passing interest - one is kept in communication loop, to know what's happened and why. And sometimes you'll see something, will act as sanity check, asking why or why not. Sometimes "dumb" questions actually are worthwhile questions.

The fact that sharing knowledge through Contribution most often entailed codified knowledge and durable channels of communication also meant that each act of sharing indirectly added to the organization's store of intellectual capital.

Type II Coaching: Dispensing Individual Insight. Coaching is similar to Contribution in being characterized by the centrality of a particular individual's unique expertise, skills or insight. Yet it is distinguished by the nature of the interaction among participants, which is more discursive, iterative, and emergently tailored to the specific learning needs of the knowledge seekers.

Coaching behavior is appropriate and necessary when a specialist's knowledge is complex, ill-structured, or situated in his or her local environment to the extent that it is largely taken for granted. Coaching was also appropriate when both parties needed to work together to clarify ambiguous knowledge needs. The specialist therefore needed the prompting of the knowledge seeker/s in order to fully refine and articulate the ideas and conclusions he or she wanted to convey. In one episode, when the GROSSO team reasoned that one or more unfamiliar ingredients in its product formulation recipe might be the cause of unexpectedly bad performance, its scientists sought expert knowledge of the chemical behavior of these ingredients from a specialist colleague. Although the specialist had vast experience with these kinds of ingredients, the chemistry discussion was limited and tailored to the particular information needs of the teams' scientists at that time. The senior scientist consulted by GROSSO members explained that, as a "custodian of science," a formal part of his role was to actively share his knowledge. However, he liked the requestor to talk through the problem, giving him the possibility to ask questions and shape his response appropriately. For this reason he preferred oral channels of interaction—specifically, telephone calls or meeting face-to-face—rather than being contacted via email. Coaching as a style of knowledge sharing accommodates greater opportunities for feedback and clarification than Contribution, and thus provides opportunities for disparately knowledgeable members to build shared perspectives and shared understanding about the topic at hand.

Another example of Coaching was identified in a learning episode in the GROSSO team, when, early in the project, the two lead technical members had exchanged thoughts and insights on their distinct site-based product and process technologies, with the objective of combining these in the development strategy. The Polymer Specialist who had many years of both professional and company experience explained how he'd started to document his historical experience for the specific benefit of his less-experienced colleague:

> I put together a history or a narrative of [a related development program of] product and process chemistry for the Team Leader, to bring him up to speed on our technology [at this site].

For his part, the team leader was able to draw on and learn from the thirty years of organizational experience of the polymer specialist. The specialist's historical narrative, addressing various chemical and physical factors believed to influence product performance, provided the impetus for a discussion between himself and the team leader. This continued through a sequence of emails, telephone calls and faxes, and resulted in a collectively developed understanding of the processing and composition issues relevant to the GROSSO product.

Coaching behavior can be initiated by both “specialists” and “knowledge seekers.” Sometimes inexperienced team members sought out more experienced colleagues for insight into a problem, as in the case above, when GROSSO’s unexpected performance deficiencies prompted the team scientists to seek out senior scientists with specific expertise using certain ingredients. On a different occasion, GROSSO’s scientific team members sought out a local senior process engineer for advice and to check their plans for a subsequent pilot trial. His attendance at their trial planning meeting enabled them to benefit from his expert clarification of the options and constraints prevailing in the prototype facility, leading to more effective planning decisions by the team.

On other occasions, individuals volunteered assistance and insight on a problem when they perceived a lack of appropriate expertise or skill among their colleagues. For example, when a manufacturing-based individual with limited experience of development work was charged with leadership of the SCURO team, the technical representative on the team, who participated in multiple development efforts, exerted himself to direct the new leader to helpful project management and development resources and approaches. Similarly, one CHIARO team discussion, ostensibly about additional equipment needs, revealed widespread confusion as to why particular polymers had different handling properties—a characteristic that was a central issue to the production members. At this point, the chemist on the team volunteered a quick chemistry lesson, complete with diagrams of the organic molecules involved, explaining simply and clearly the relationships between the chemical structure and the physical behaviors of the materials.

The timing of Coaching initiatives can vary but team members most often sought Coaching interactions when they were particularly seeking confirmation of ideas and/or new directions to extend their current understanding. This kind of interaction provided a “sounding board” for clarifying and consolidating knowledge of project opportunities and alternatives. As one member of CHIARO commented,

> I need kindred spirits to talk to, to discuss how and why we’re doing what we’re doing. I spent a lot of time talking on the phone to other scientists, mostly about the philosophy of what we’re trying to do, getting moral support.

The contrast between Contribution and Coaching can be compared to the difference between off-the-shelf medicines and prescription medicines. In the latter case, a pharmacist dispenses medicines to address the particular complaint of an invalid with careful attention to the support needs of the invalid. Similarly, in Coaching, a team member "dispenses" his or her specialized expertise and judgment, taking into account the particular information needs of his/her colleagues regarding a particular issue. However, from a learning outcome perspective, the intention of these two sharing types is very similar; the greater insight of one participant regarding a particular topic is intended to be replicated among other team members. In actual practice, the process of interaction often entailed *adaptation* of the specialist's knowledge to the problem at hand and, as a side-effect, greater *self-discovery* by the "specialist" of his or her own understanding. Coaching also had the additional advantage of cementing personal relationships and trust among participants as a result of the more intimate interaction among those participants.

Type III Collaboration: Discovering Collective Insight. In contrast to Contribution, in which individual members seek to encourage convergent understanding on a particular topic, *Collaboration* more often entails divergent knowledge exchanges that result in a problem being refined or reframed. Effective Collaboration involves the engagement of the diverse disciplinary knowledge, judgment and experience of a variety of people—both team members and others—catalyzing the creation of collective insight into a novel situation.

Collaboration is characterized by a predominant role for the group as a collective, and by the input of multiple funds of knowledge from representatives from various occupations and locations. In this study, although it was efficient for virtual team members to work independently when deep specialized knowledge was required on a task, there were inevitably occasions when problems were unfamiliar, ambiguous, or just complex. Under these circumstances, team members recognized the importance of examining the problem from multiple angles:

> These different perspectives are good. It makes you recheck your thinking, a sanity check. You need protesters, a devil's advocate… This diversity is positive and essential - it reduces the failure likelihood. —CHIARO Process design engineer

Collaboration occasions, therefore, often involve the generation of previously lacking shared assumptions or frames of reference.

Individual participants' knowledge relevant to the problem at hand was rarely fully codified, so simply writing down what they knew was of little value. They were, however, able to articulate what they knew in response to prompting by the ideas and concerns described or demonstrated by others. Through such interaction, each participant's knowledge became more "discursively available" (Giddens, 1984). Collaboration therefore depends on achieving multilateral, highly discursive interaction and was most effectively achieved via synchronous, highly interactive channels where spontaneous feedback in real-time was possible. Inevitably, face-to-face interaction was preferred and was imperative in some situations where knowledge could only be demonstrated in action—such as skill to use a tool or perform an experiment. For example, in one episode the BIANCO team only realized the true value of their Technical Specialist's production knowledge when he was physically present at the production site during a production trial. Similarly, the NERO team leader recounted how the team was only able to integrate the Experimental Scientist's insights about the prototype production process when he was able to visit the production site and work directly with the production members. Despite team members generally expressing a preference for face-to-face interactions, dispersed teams in this research setting did, however, also successfully generate collective insights when using audio-conferencing channels.

Whereas Contribution occurs at times when an individual might have achieved personal (perhaps temporary) "closure" or certainty on an issue, Collaboration is, in contrast, a behavioral response to a situation of collective equivocality or uncertainty. In this setting, a virtual team (or a subset thereof) either confronted many potential avenues of action requiring a decision on how to proceed, or its members had insufficient information at hand to even identify a path forward. In both types of situations, an appropriate response required a diversity of knowledgeable participants to generate and evaluate options. For example, when their customer's demands presented a unique technical challenge, the BIANCO technical and manufacturing members needed to integrate their different perspectives and insights to decide on a solution. The scientists identified several composition alternatives, but manufacturing members pushed for simplicity in the process, while the customer liaison representative agitated about meeting the customer's tight schedule. The Team Leader described the challenge of incorporating the diverse perspectives of BIANCO scientists, engineers and operators:

> We had one of our conference calls scheduled after this customer feedback, so we had our extended technical team on the line, [doing] lots of head scratching, saying "what could one do?" This is where it gets kind of interesting with all the different personalities. [The product development specialist] is a technical guy. He likes playing around with technical stuff so he's saying, "well, you could add this, you could add that…." You can always add something!

> Meanwhile, my background's manufacturing —and also because of the timeframe we're on—so my focus is, "we don't want to start adding variables, we want to nail things down as fast as we can." So [in the team] we're trying to find the right balance.

Through acknowledging and accommodating these different inputs, the team collectively developed sufficient insight to incorporate two new ingredients, which jointly might modify the product as required.

In terms of its direct effects on learning, effective Collaboration practices facilitates the group's collective *discovery* or *creation* of new insight pertaining to the team task. Moreover, the process of interacting intensely and iteratively with disparate and distant colleagues supports the development of personal, trusting relationships that create a foundation for team effectiveness beyond the current task, and thus enhances the participants' ability to work together in the future (Hackman, 1987).

4.2 A Repertoire of Knowledge Sharing Practices

In addition to identifying distinctions in the styles and outcomes of knowledge sharing efforts in these virtual teams, our practice-oriented analysis also highlighted how these different sharing practices operated as complements to each other. Our focus on learning episodes revealed that different types of problems or knowledge gaps demanded different learning responses. Thus dispersed teams learned about their project task through the reflections and actions of both individual members working independently on separate aspects of the project and groups of members working together. As a result, teams required different types of knowledge sharing in order to ensure that the learning at these different levels and in different places and times was integrated into team level insights. Over time, as new insights were gained, new problems and new activities were identified, which led to more learning, more knowledge sharing and, ultimately, successful learning outcomes.

For example, consider one learning episode, "Trial 2," from the BIANCO team. The BIANCO team, dispersed in five sites on three continents, was developing a new product for a new customer in a highly strategic market sector. Using novel techniques in their first trial, the team had successfully delivered a prototype to the customer who evaluated it favorably but pushed for an improvement that hadn't been raised earlier. It was not immediately apparent how this might be achieved technically; in addition, the team was under extreme time pressure to deliver the next samples. The team initiated a response to the problem by brainstorming, via teleconference, with the extended technical team, including members from manufacturing, engineering and chemistry backgrounds on possible paths forward. Input from the scientific members highlighted possible new ingredients to incorporate, however manufacturing members pushed for production simplicity while the team's customer contact agitated about the tight timeline. Through a *collaborative* process of engaging and accommodating these multiple perspectives on both technical and non-technical issues and alternatives, the team developed insight to narrow down their possible options to two additional ingredients that might adjust the product as required. Although they now had a plan of action, the team still faced the new problems of figuring out how and how much of these ingredients to incorporate. Subsequently, the team relied on its experimental scientists to experiment with formulation recipes to gather additional information on the likely impact of one of the relevant ingredients. A day before the second trial was scheduled, the lead experimental scientist *contributed* conclusions and guidelines regarding the first ingredient, signaling that it would help although, on its own, it would not get them far enough. But, as the team leader explained, they could extrapolate from this feedback to judge that "if we had time, and if we added [ingredient 1] and added [ingredient 2] on top, we had a high chance of being where we needed to be." Team learning from the scientists' *contribution* is evident in the understanding exhibited by production members who built on the experimental scientist's input to make effective judgments regarding the actual production process. Parallel preparations by engineering and manufacturing members to identify ingredient suppliers and to prepare for handling additional ingredients in the manufacturing process meant that the team was able to successfully run the trial, incorporating both ingredients without a hitch. The combined knowledge of the team was both embedded in the product sample received and found satisfactory by the customer. This team level insight was also documented, by the product development engineer, in the trial report for future reference. The distribution list for his *contribution* included both the team and a larger group of employees with an interest in or responsibility for such production activities, thus creating the possibility for learning beyond the team. In summary, a sequence of different but complementary knowledge sharing engagements resulted in a successful team outcome and new learning for the team.

Similarly, a key learning episode for GROSSO was, as noted above, triggered by unexpected performance deficiencies in a prototype product. A *coaching* dialogue between team members and local chemistry specialists for advice as to the possible origins of their product's shortcoming led the team to identify new avenues to test a single ingredient. They followed up these new experimental avenues by engaging the practical skill of a peripheral member who *contributed* results and conclusions to the project electronic space. As a result the team was able to make subsequent decisions with additional experimental information at hand.

In the preceding cases, Coaching and Collaboration behaviors advanced team insights that created suitable conditions for subsequent Contribution behavior. When a situation or issue was particularly complex or unfamiliar to most team members, Coaching could also act as an "add-on" to Contribution in order to bring team members up to speed with the specialist. This sequence of sharing activities occurred in the CHIARO team, in its efforts to choose a base polymer to use in a new local manufacturing process for a group of clear film products. The polymer chemist had previously *contributed* insights regarding the connection between particular chemical properties of the team's chosen polymer and its handling properties, explaining that an alternative material exhibiting similar easy handling might be manufactured locally. Later it became apparent during a face-to-face team meeting that some but not all team members had fully understood the implications of using different materials, as suggested by the chemist in his earlier email. This encouraged him to *coach* his non-chemical team mates through the relationships among the polymer structure, the desired end-use characteristics of the product, and the manufacturing handling needs in more detail, by making use of diagrams and accommodating clarifying questions.

In summary, dispersed team members use the three different knowledge sharing practices as a repertoire in order to integrate, at the team level, new insight acquired in different places and at different times.

5. Discussion and Conclusion

Although the literature on knowledge transfer between organizational units and knowledge sharing among individuals has revealed variety in the characteristics of these engagements, thus far there has been little detailed exploration of the varieties of knowledge sharing practices and their outcomes. Further, there has been little discussion of the existence or need for variation in how knowledge is shared in virtual settings. This research contributes firstly by identifying distinct knowledge sharing practices at the virtual group level of analysis, and secondly in highlighting their interaction. In this study, we found that there are multiple ways of sharing knowledge in virtual teams, which provide a means for knowledge to be transferred from an individual to the group, within the group, and from the group to the organization. Specifically, these findings show that, dispersed teams enact three distinct knowledge sharing approaches and that dispersed team members choose different knowledge sharing practices from this repertoire in order to integrate, at the team level, what is learned in different places and at different times.

Furthermore, our findings show that these different practices are complementary in that they enable learning of different kinds and of varying scope—both by the team and by the organization. Contribution enables dispersed team members to sequentially *replicate* a specialist's own understanding of a particular issue. Coaching enables team members to learn from and *adapt* the specialized knowledge of particular individuals. Collaboration describes the highly interactive and iterative discussions and shared activity through which members are able to synchronize their various experiences to *discover* a new, shared insight. These different practices also have different secondary effects. For example, contribution practices support replication of knowledge but, owing to their mostly written form, also often have the side effect of contributing to a longer-term organizational memory beyond the lifespan of the particular project and team. This effect can be particularly important for virtual teams who are often "invisible" to the rest of the organization, and thus must create their own visibility and legitimacy through publicizing their work and results. Coaching and collaboration practices enable adaptation and creation of knowledge and, in addition, often create side-opportunities for networking and relationship building, which contribute to more effective knowledge exchanges beyond the immediate need. Moreover, knowledge sharing in general is likely to build the transactive memory of the team (Wegner, 1987), a process that is particularly critical in the dispersed setting since team members have limited opportunities to absorb knowledge of what others' know through implicit means.

The complementary nature of these knowledge sharing practices is manifest in the ways that they are invoked in conjunction during the course of a learning episode. For example, an insight contributed by one member working independently on one task often provides the necessary input to stimulate a coaching or collaborative exchange with other team members, which, in turn, positions the team to delegate tasks and prompts further contribution behavior. Thus this conceptualization of team-level knowledge sharing mimics the “feed-forward and feed-back processes of learning across the individual, group, and organizational levels” as identified by Crossan et al (1999).

Prior research has not explicitly recognized the value of a repertoire of sharing patterns for effectively accomplishing dispersed work—even though different sharing styles have been separately observed in other contexts. For example, contribution-like behavior has previously been noted as occurring among otherwise unassociated individuals—either interacting directly (e.g. Constant, Sproull, & Kiesler, 1996) or indirectly via a common electronic knowledge repository (e.g. Goodman & Darr, 1998)—although not in the context of a specific group endeavor. Likewise, collaborative behavior—intense, highly interactive and generative knowledge sharing behavior—has been previously observed, both in teams (Nonaka & Takeuchi, 1995) and occupational communities (Brown & Duguid, 1991), however these were in co-located settings. Other researchers applying a more macro level of analysis have observed parallels to Contribution and Coaching styles of sharing in different knowledge management approaches. For example, in professional service firms, Weiss distinguished KM processes that she labeled “collection of knowledge” and “connection to knowledge” (Weiss, 1999). Hansen et al similarly describe “codification” and “personalization” knowledge management strategies, and even suggest that these approaches are more effective when applied exclusively (Hansen, Nohria, & Tierney, 1999).

In contrast to prior work, the findings of this research show firstly that, rather than being constrained to co-located settings, Collaboration is also possible within dispersed group settings—albeit manifesting different characteristics and demanding different preconditions to more proximate interchanges. Moreover, the findings suggest that, at the team level of analysis, rather than being mutually exclusive options, Contribution, Coaching and Collaboration knowledge sharing practices can and should be used in conjunction to enable dispersed, diverse members to build sufficient common knowledge to accomplish their joint objectives. We suggest that the capacity to engage effectively in a variety of knowledge sharing practices is critical for dispersed, diverse teams whose members frequently undertake specialized knowledge work individually and independently of each other, but also need viable ways to integrate and build on the diversity of expertise and perspectives that they collectively embody.

4.2 Conclusion

The study combines ideas about knowledge transfer and knowledge sharing to provide a deep understanding of the nature of knowledge sharing in cross-functional, geographically dispersed new product development teams. It advances the literature on knowledge management and organizational learning by exploring organizational knowledge processes at the group level in dispersed settings, and offers a model for effective knowledge sharing processes within other groups with similarly-configured memberships.

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