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ORGANIZATIONAL TETRIS: HOW COMMUNITIES OF PRACTICE COORDINATE SPECIALIST KOWLEDGE IN THE FIRM

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ABSTRACT

Construction and Engineering organizations are increasingly adopting communities of practice (CoPs) as a way of managing knowledge. These CoPs consist of topically bounded membership, limited managerial control, and some form of online repository or search tool. When they function well, CoPs bring together dispersed professionals who freely share knowledge with one another to globally align technical practice, solve project based problems, create new knowledge, and increase the flexibility of the firm to react to market changes. Interestingly enough, the form that these CoPs take is significantly different from its theoretical roots. Originating in cognitive learning and organizational learning literature, the scholars who coined the term "communities of practice" saw them as localized, tight knit, organically emergent groups that characterized the way that people naturally learn, work, and innovate. CoPs in business practice are larger, subject to higher degrees of hierarchical control, and more multi-disciplinary than ever before, pushing them further away from their theoretical origins. Adopting a knowledge based view of CoPs as a mechanism for optimally coordinating the knowledge of specialists, this paper examines the types of coordination facilitated by CoPs in current business practice. The findings identify four different types of connection characterized by different degrees of overlap in specialists' knowledge bases, and discover that each type of connection facilitates distinct forms of knowledge coordination. Using the framework of four types of connection, this paper explains how CoPs facilitate the creation of social networks that bring together a wide variety of different knowledge bases into cohesive communities, fitting the pieces of the organization neatly together like a successful game of tetris.

INTRODUCTION

Intra-firm communities of practice (CoPs) have proliferated in the past few decades as a knowledge management strategy within project-based firms. These project-based firms are notoriously fragmented, as each project has a distinct start and stop, with project pressures and needs often superseding knowledge transfer between projects. As such, many project-based firms tend to emphasize projects over organizational structure and processes (Lindkvist 2004). As a result, project based organizations are especially prone to repeat mistakes, continuously solve the same problems, and dedicate resources to issues that have already been addressed elsewhere in the organization. However, because construction and engineering are knowledge-based industries, coordinating and exchanging knowledge across projects can create learning opportunities that arise from disseminating project practices to other projects (Sydow et al, 2004) and help improve the performance of multiple projects by integrating knowledge from different geographies (Cross et al. 2010; Javernick-Will 2009), or areas of the company (Cummings 2004).

To help integrate knowledge within these fragmented, project-based industries, companies have worked to create internal groupings of employees bearing the namesake of CoPs, with the goal of sharing knowledge among distributed groups of professionals. The definition ascribed to CoPs is increasingly generalized, such that managers view CoPs as *"a group of professionals, informally bound to one another*

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through exposure to a common class of problems, common pursuit of solutions, and thereby themselves embodying a store of knowledge" (Manville and Foote 1996). In fact, their application has become so widespread that the term "community of practice" has become part of the standard business lexicon.

Interestingly enough, the business application of CoPs is not easily traceable to its theoretical roots (Amin and Roberts 2008), causing widespread debate as to the definition and purpose of CoPs *as they are being applied in firms* (Kimble and Hildreth 2004; Lindkvist 2005; Roberts 2006). Namely, CoPs were originally conceived to describe the importance of practice in learning theory, not to create a new tool to manage knowledge (Amin and Roberts 2008). Both the cognitive (Lave and Wenger 1991), and organizational learning (Brown and Duguid 1991) perspectives used the term "communities of practice" to emphasize the importance of practice in learning theory. As acknowledged by Paul Duguid: "*Papers also tend to make a lot of the purposefulness with which organizations create or manage communities of practice. So doing they tend to make communities of practice the outcome of management fiat, and not of practice."* (Amin and Roberts 2008)

In contrast with the theoretical roots of CoPs, practice-oriented definitions classify CoPs as "a group of individuals make[ing] a collaborative effort to improve their practice" (Saint-Onge and Wallace 2012 p. 33) and management scholarship has touted CoPs as "a vehicle of collective learning and knowledge creation within organizations" (Ardichvili 2008), thus elucidating the ability of CoPs to "drive strategy, generate new lines of business, solve problems, and promote the spread of best practices" (Wenger and Snyder 2000). These statements indicate that the theoretical justification for CoPs have shifted toward coordination and collaboration of knowledge specialists, and away from injecting practice into learning theory. This represents a tangible shift towards the knowledge-based-view of the firm (KBV), originating from strategic management. According to this perspective, the firm is an institution for integrating the knowledge of specialists through cooperation. Namely, the goal is to organize specialists into an optimal configuration to efficiently apply knowledge to produce a product or service (Grant 1996). As the use of CoPs has shifted towards the KBV, scholars have increasingly noted the insufficiency of learning theory to explain the form and purpose of CoPs in current business settings (Lindkvist 2005). In contrast, the KBV suggests that communities of practice play an important role in knowledge coordination within the firm (Brown and Duguid 2001).

In spite of this supposition, there is very little empirical evidence demonstrating the actual types of coordination occurring within CoPs in practice. Because there is a dearth of empirical study, and CoPs are largely self-governing structures, their contribution to the organization is questionable (Kimble and Hildreth 2004). To remedy this gap and determine the strategic value of CoPs, we ask the following research question: *How do CoPs in business practice coordinate specialist knowledge?* To answer this question, we first need to understand what makes the application of CoPs distinct from their theoretical roots.

COMMUNITIES OF PRACTICE IN PRACTICE

Scholars agree that the distributed groups of experts currently being called CoPs are radically different from their theoretical origins (Amin and Roberts 2008). When they were originally theorized, the term "community of practice" was not intended to describe a formal organizational structure. It was rather expressing a practice based view of learning as individuals form identities and progress from the periphery to the core of a social group (Lave and Wenger 1991), and to loosely identify the informal ways that people actually work, learn, and innovate within formal organizational structures (Brown and Duguid 1991). When managers saw the knowledge creation, collaboration, and learning that occurred when people participated in situated learning, they tried to create structures that would *"increase knowledge*

creation as well as expand the extent and accelerate the speed at which knowledge is exchanged around the organization" (Saint-Onge and Wallace 2012). In most global organizations, managers began using CoPs as a "way of managing knowledge" (Roberts 2006) through topical communities created to facilitate knowledge sharing across distributed groups of professionals that faced common problems. In their current application, CoPs deviate from their theoretical origins along three significant dimensions: size, governance, and disciplinary scope.

To begin, CoPs, as they are applied in practice, are too big. When Brown and Duguid (1991) defined CoPs as "tight knit" groups, they likely did not intend the term to be applied to loosely coupled, geographically distributed groups with thousands of members. This has led more recent scholarship to re-define the business practice as electronic "practice networks" (Brown and Duguid 2001) that are loosely knit and geographically distributed, or "collectivities of practice" characterized by an knowledge base that is distributed and individualized, but aligned through specific project goals (Lindkvist 2005). Both the size and spatial distribution of global CoPs decrease key social aspects of the community like "local lore, shared stories, inside jokes, and knowing laughter" (Wenger 1998 pp. 125–126). Without these critical characteristics, situated learning is difficult, because members are not legitimately participating in a community (Roberts 2006).

The next significant deviation of practice and theory is in CoP governance. When Brown and Duguid and Lave and Wenger originally conceived CoPs, they envisioned groups of people that operated relatively free from the hierarchical control of the organization. Only later did scholars begin to postulate that CoPs may be amenable to hierarchical control, or managerial oversight (Wenger et al. 2002). In theory, CoPs operate outside of hierarchical control because they are not initiated by management, but rather emerge organically as the way that people work, learn, and innovate in community settings. In current practice however, the boundaries of CoPs are frequently manipulated by managers to increase the scope of membership (Saint-Onge and Wallace 2012 pp. 78–79). The introduction of this type of hierarchical control is new to CoPs, and has the potential to change their nature.

Lastly, because the boundaries of CoPs are decided by managers rather than enacted, the scope of these communities has expanded beyond a single "field of mature practice" (Lave and Wenger 1991 p. 122), and now encompasses a distributed body of knowledge (Becker 2001) that is "radically dispersed, distributed or individualized, being impossible to gather or comprehend by any single, overseeing mind" (Lindkvist 2005 p. 1200). To understand the role of CoPs in coordinating specialist knowledge, we have to consider the interactions between many, diverse knowledge bases. These nebulous, geographically dispersed, inter-disciplinary groups bear the namesake "communities of practice," and are marketed as "the most significant, tangible example of knowledge management at work in an organization" because of the enormous benefits that they produce (Saint-Onge and Wallace 2012). So we see then that CoPs must play a vital role in integrating and coordinating a wide variety of different knowledge bases, yet the way in which they do this in business practice is fundamentally unknown.

To explore the ways in which CoPs coordinate specialist knowledge, we will start by identifying connections between specialists using social network methods (Chinowsky and Taylor 2012). These informal networks of knowledge sharing connections, versus formal hierarchical structures, link professionals across business lines, geographic, and epistemological boundaries to coordinate specialist knowledge and produce unique products (Chinowsky et al. 2008, 2009). These "social networks", or relationships between employees that constitute actual work practice, rather than proscribed organizational structures (Cross and Parker 2004), and are critical for intra-organizational knowledge exchange and coordination. We then gather qualitative interview data about connections occurring within

the network. Through CoP members' descriptions of their own connections, we can create an emergent framework describing the types of coordination occurring within CoPs, and how this coordination is affected by characteristics of CoPs in business practice.

METHODS

In practice, CoPs have evolved on a separate trajectory from the theory supporting them. To build theory based on practice, we analyzed three CoPs within two firms to explore the interactions between specialists with diverse knowledge bases. We focused specifically on coordination that involved knowledge exchange, rather than information or data (Alavi and Leidner 2001). We did this by asking CoP members with whom they shared *knowledge* defined as "*information that directly supports your ability to act in your particular job role,"* and then verifying this construct through follow up interviews with a stratified, quota sample of each CoP. Because our unit of analysis is knowledge sharing connections, and not discreet exchanges, it became evident that knowledge, information, and data exchange are not distinct phenomena, but rather occur in tandem as professionals engage in practice (Orlikowski 2002). Through the interviews however, 93% of connections satisfactorily demonstrated that knowledge sharing occurred in addition to information and data exchange. This was evidenced by asking interviewees what types of knowledge they would typically exchange with one another, and evaluating the exchange using a definition of knowledge as information that affects belief (Dretske 1981). That is to say, that when knowledge was exchanged, it was evident that the exchange changed how one or both participants thought about the project or problem at hand. This practice based view of knowledge is consistent with prior literature (Alavi and Leidner 2001; Orlikowski 2002). Through investigating these interactions we are able to build theory regarding the role of CoPs in coordinating the knowledge of their members. First we deployed social network surveys to the entire CoP, to create infographic maps showing who was connected with whom. From these maps, we employed a stratified quota sampling technique (Singleton and Straits 2005) to select interviewees from different geographic locations, as well as from the core and periphery of the network. To tease out the types of coordination occurring between specialists in global CoPs, we selected a qualitative, semi-structured interview methodology which enabled us to ask detailed questions about the type of exchange in specific knowledge sharing connections.

Social network survey and interviewee selection

To help evaluate types of coordination that occur in multinational CoPs, we first deployed social network surveys to each of the three CoPs studied. Each CoP is large, geographically distributed, facilitated and defined by managers, and covers a knowledge base that is too large for a single individual to comprehend. For purposes of confidentiality, we use the pseudonyms "Company A" and "Company B" for the two companies involved in the study.

Process Improvement CoP: Members work as internal consultants for construction and engineering projects to provide process improvement services for Company A. Membership includes a wide variety of disciplinary backgrounds from computer modeling to project management. There are 273 members distributed across more than 10 countries, with membership at all hierarchical levels and in each business line. Members have access to an intranet that links to a project report repository and online process improvement forums.

Transportation CoP: Formed along one of the major business lines of Company B, the members of this CoP all work in the transportation sector of business. This includes 365 members across a wide variety of disciplinary groups and more than 10 countries, although the majority of members are concentrated in North America. An online platform was initiated by managers approximately 5 years ago, and it includes a search function, document repository, and online forums.

CAD CoP: Rather than bounding itself along a business line, the CAD CoP was created to link global practitioners using computer aided design (CAD). There are 1153 members across all business lines and geographies within the company. Topically, CAD includes a range of different software that is used to create construction drawings across all industries and geographies. Housed within Company B, the CAD CoP has access to the same online platform as the Transportation CoP, although the structure and content of online interactions is specific to CAD rather than transportation.

Survey response rates were 36.6%, 35.2% and 29.9% in the Process Improvement, Transportation, and CAD CoPs, respectively. The survey was sent to the entire population of each CoP, and each participant was asked *"with whom have you shared knowledge in the past six months?"* where knowledge was defined as information that directly enabled action in participants' particular job role. Within the survey form, participants could select their connections from complete list of CoP members. Using the data from the survey, we selected interviewees using a stratified sampling technique (Singleton and Straits 2005) so that we could gain perspectives from different geographies, as well as from the core and periphery of the network. To do so, we calculated the number of connections held by each person within the network, and stratified our interviewee selection with high, medium, and low levels of connection.

Semi-structured interviews and qualitative analysis

For each interviewee, we selected three knowledge sharing connections from the survey data to discuss in depth, and created customized interview guides to ask participants about those specific connections. While qualitative research typically employs a convenience sampling technique to achieve conceptual saturation, we used a sampling technique based on social network surveys to reduce the effects

of self selection and increase the internal and external validity of our findings. We conducted semi-structured interviews via phone call that lasted between 30 and 50 minutes. During the interviews, participants were asked to describe their job role, their involvement in the CoP, and the selected knowledge sharing connections from the survey. For each connection we asked if participants were aware of their connection's area of expertise, the type of knowledge that they share with that person, and the degree of overlap between their knowledge bases.

In total, we conducted 27 interviews in the Process Improvement CoP, 22 interviews in the Transportation CoP, and 28 interviews in the CAD CoP. Interviews were recorded, then transcribed, and entered into QSR NVivo, a qualitative analysis software. To analyze the data, we followed a process similar to that outlined in Haney et al. (1998) to create an emergent coding structure. Initially, two researchers independently examined the data to search for emerging themes of coordination between specialists. There was a particular emphasis on the type of knowledge being shared, and the degree of overlap between specialists' knowledge bases. Next, the two researchers compared notes to discuss any discrepancies and the emergence of prevalent themes. After reaching consensus, we created a coding structure to typify these connections into groups characterized by different degrees of overlap in participant's knowledge bases. The emergent categories were collectively exhaustive and mutually exclusive in their description of connections. Once these concepts were developed, two researchers analyzed the interview data independently, and checked the reliability of these categories to increase both reliability and construct validity. As the coding structure was applied to our interview data, we periodically conducted quality control checks to verify consensus among the two researchers. In total, we asked participants about more than 150 knowledge sharing connections that were coded into our framework.

RESULTS

During the initial examination of the data, it was apparent that CoP members had a high level of awareness of the scope of their own knowledge base, and how that related to other members' knowledge bases. From this initial observation, we identified four types of connections characterized by different degrees of overlap in participants' knowledge bases. The type of connection quickly became a dominating concept, because the type of coordination (i.e. problem solving or task coordination) between specialists depended on the degree of overlap between subjects' knowledge bases.

Professionals with a high degree of overlap typically have the same job roles and similar knowledge bases. We call these "overlapping" connections, even though two knowledge bases are never perfectly identical. Overlapping connections tend to coordinate specialist knowledge through problem solving, sensemaking, and the identification of subtle expertise. Next, there were a group of professionals with very little overlap in their knowledge bases, but both were needed to coordinate to accomplish a common task. We called these "complementary" connections. Within the transportation CoP, for instance, there are both economists and project managers. Both work on transportation projects, are familiar with what the other professional is capable of, and yet unable to step into each others' job roles. Complementary connections occur in all three CoPs, and tended to coordinate specialist knowledge by task focused coordination, cross pollination of ideas, and creating networked connection between pockets of different expertise within the organization. Next, we identified "growth" connections, in which a knowledgeable professional is teaching a less knowledgeable one. Although the exchange in growth type connections is one sided, specialists coordinate with one another in training, education, and reproduction of expertise. Finally, there were a few rare occasions when CoP members experienced "non-overlapping"

connections, in which their two knowledge bases were so different that there was no coordination between specialists. These findings are summarized in Table 1.

Table 1 - Types of connection and coordination

Type of connection	Visual representation	Types of Coordination
Overlapping		Problem Solving Sensemaking Identification of subtle expertise
Complementary		Task coordination Cross pollination of ideas Structural holes
Growth		Training/education Replication
Non-Overlapping		No coordination

To maintain anonymity, we use pseudonyms to identify interviewees in these quotations. Due to the relational nature of the quotes, we elected to use names rather than impersonal identification codes. All four types of overlap were observed in each of the three CoPs, although only selected quotations appear due to limited length requirements.

Overlapping

One way that specialists coordinate their knowledge within CoPs is problem solving, sensemaking, and building awareness of subtle areas of expertise with other professionals who are similar to themselves. Within all the CoPs studied, there were connections characterized by a high degree of overlap between the two participants' knowledge bases. In these cases, the two employees are mostly interchangeable as knowledge resources in the company because they perform similar job roles, and have the same basic knowledge base and experience.

While two people will not have exactly the same experience, knowledge, and ways of thinking, overlapping interactions allow professionals who perform similar tasks to coordinate richly on a wide variety of deeply contextual issues. As one respondent from the Process Improvement CoP described *"both of us think along the same lines when we are looking at what we need to do and how to make improvements and those kind of things… I think we are very aligned because we both have the same background."* This alignment generally facilitates high quality exchange, because CoP members do not have to educate the other on their ways of thinking or fields of work. This enables close coordination between specialists who wish to brainstorm and solve problems.

Individuals with overlapping type connections also coordinate through sensemaking (Weick et al. 2005) to define their roles and field of practice. When this happens, it pushes the company towards consistency of global practice and provides opportunities to critically review and improve technical

practice. Kerry (Process Improvement CoP) discussed her connection to a co-worker, saying that "*We were just playing the same role of coordination for different regions… we were just working together and defining the roles or the activities for the different regions."* Even though Kerry's connection works in South America while she is in North America, they are able to mutually define their profession through sensemsking. In this way, overlapping connections create global consistency of practice by aligning geographically dispersed employees. Their mutually shared knowledge and experience allowed them to interact on a deep level to define their field

Finally, a high degree of overlap in knowledge bases facilitates networking to help specialists locate subtle areas of expertise and create latent connections that can be activated when needed. In the CAD CoP, one interviewee shows how his overlapping connection has allowed him to precisely identify Bill's strengths. *"Bill could probably do 80% of the things I could do and I can do 75% of the things he can do. I don't design as well as Bill, but there are certain features that have been updated in CAD that I have more exposure to."* Specialists do not need constant access to the subtle strengths of their colleagues, although identifying these strengths in others will create latent connections that are activated when needed. As Samuel from the Transportation CoP stated about a colleague "*he has a lot of common sense and a lot of experience. If I could not resolve a problem on my own I would go to him, but I haven't come across anything that I needed his input for in a couple of years."* Although Samuel has not interacted with this connection in quite some time, he recognizes the value of his experience and knows he can reference it if needed.

So then, one way that specialists are coordinating with one another in global CoPs is by problem solving, sensemaking, and networking through overlapping connections. These interactions facilitate immediate solutions to deep contextual problems, ensure continuity of best practice and innovation within specific fields, and generate latent networks of connection to help locate more subtle individual expertise within the company.

Complementary

Through complementary connections, specialists coordinate their knowledge through tasks requiring both knowledge bases, cross pollinating ideas, and forming network bridges to different areas of expertise in broadly focused CoPs. Complementary connections occur when two CoP members have different areas of expertise, yet both knowledge bases are required to accomplish a given task or goal. Generally both have a high awareness of the other's area of expertise, and what they are capable of doing within a particular task, but the two participants do not have the knowledge required to switch jobs.

Although complementary connections can be initiated for a variety of reasons, this type of coordination is frequently task focused. Because complementary knowledge bases are required to perform complex tasks, it is the task itself that helps bridge the two knowledge bases. For instance, when one employee was asked about her connection with Sam, she stated *"Sam is a hydraulic engineer. If we were designing something and it is going to affect stream flow, or stream capacity, we will share knowledge back and forth to coordinate, but as far as technical knowledge; there is not a lot of exchange there."* (Marguerite, Transportation CoP). As a structural engineer, Marguerite has very little technical overlap with Sam, yet there are times that her limited knowledge about a task she is working on compels her to contact Sam. During these times, they need to interface with one another to execute a complex project. This leads to a high level of awareness of others' knowledge bases, but not the ability to do what they do. When brought together on a common task, the co-dependency of specialist knowledge becomes very apparent. Samuel spoke of one connection within the CoP saying *"we are not doing the same kind*

of work, as if she was also designing rail stations, but there is a very real need to access the knowledge that she holds." (Samuel, Transportation CoP).

Within complementary connections, specialists also coordinate through non-task focused cross pollination of ideas. The application of several diverse knowledge bases to solve problems can usefully create more robust solutions. As one CoP member stated, "*The risk is when you all have the same mindset, you all think the same way and make the same mistakes, so it's good for different people to mix in. My boss is from a completely different background, and we think differenty, but we come up with a better overall solution." (Faye, Process Improvement CoP).* While cross pollination of ideas can be quite on a more general level, there is not very much benefit to sharing in depth technical or field specific knowledge. Arthur in the CAD community demonstrates this concept "*We do completely different lines of work. He's a structural modeler, I do alarm systems. So we might talk about Revit, but we wouldn't talk about the finer details of what we do."* In this case, the two CoP members can usefully share ideas about the software that they use, because recognize the inefficiency of everybody knowing what everybody else knows (Grant 1996). This only allows them to coordinate through cross pollinating higher level ideas and perspectives, not the rich, contextual content that can be exchanged in overlapping connections. .

Finally, complementary type connections provide CoP members with access to diverse knowledge bases within the organization. As Burt (1992) theorized, this produces "structural holes" in the network that provide swift access to resources within the community, even if not immediately apparent. Complementary connections are like a bridge between different topical knowledge bases that allow people to use their connections to find the right specialist for their project. Talking about one of his connections, Chris in the CAD CoP stated *"He's got a good idea of all the activities our company is doing in and around CAD and especially BIM. So if I approach him with a question, either he knows or he will point me to someone else who knows. We've got quite different roles though; we couldn't swap our jobs even if we wanted to."* Here, Chris's connection is giving him access into the world of CAD and BIM expertise, which provides him with answers to knowledge based questions he might have.

In addition to overlapping type interactions that occur within global CoPs, complementary connections facilitate different types of coordination between knowledge specialists. Rather than connecting experts with similar knowledge bases, complementary connections facilitate coordination between specialists with diverse areas of expertise. Specifically, complementary connections within CoPs facilitate coordination of specialists through task coordination, cross pollination of ideas, and interpersonal ties that bridge different areas of expertise within the company.

Growth

While overlapping connections allow experts to mutually define their field, growth connections allow continuity of practice by passing knowledge from more experienced to less experienced professionals. In growth connections, there is a fairly clear mentor and mentee, where the mentor could perform most, if not all, of the mentee's job role. Coordination occurs through training and education as the less knowledgeable participant tries to accumulate expertise and grow their knowledge base into one that overlaps with their mentor.

Within CoPs, growth connections are frequently initiated through formal organizational roles, where the difference in knowledge base is linked to tenure in the field or organization. Coordination between specialists happens through training and replication as experts with more experience pass on what they know, growing their mentees' knowledge bases and replicating their knowledge. Anita, talking

about her mentor within the CoP states that "*I am sure that he could do everything I am doing, and I would only be able to do a small portion of what he does due to his experience. There is a 30 year age gap between us." (Anita, CAD CoP).* Because of the knowledge gap between mentor and mentee, it is clear that coordination consists of one party learning from the other. Claire stated that "*Engaging with Bill is more like a mentor session because of his vast amount of knowledge and tenure within Company A" (Claire, Process Improvement CoP).* In both of these cases, the speakers do not have as much time or experience within the organization as their connections, and coordinate with them by learning from them, and being coached.

Over time, the mentee learns and grows, significantly narrowing the gap between the two knowledge bases. Growth connections coordinate specialist knowledge through reproduction, such that at some point, the connection can be considered overlapping rather than growth. When asked about the degree of overlap between his knowledge base a colleague's, Charlie stated that "*now there is a lot of overlap, but at the time we started interacting, I didn't know anything at all."* Throughout this process, the exchange between mentor and mentee becomes richer, more detailed, and more contextually nuanced. The tacitness (Polanyi and Sen 1983) of the interaction tends to increase as the mentee becomes more knowledgable, and acquires the vocabulary required to discuss problems related to the field. Janice says that "*I finally got to a point where I knew enough to have a conversation with him. It became more like bouncing ideas off one another instead of me taking direction from him" (Janice, Process Improvement CoP).*

Non-Overlapping

Because CoPs are topically bounded to specific practices or business lines, it is uncommon for CoP members not to have any useful overlap in their knowledge bases. On several occasions however, members described non overlapping connections, where there was no useful coordination of knowledge. When asked why a particular connection was not seen as useful, Davidson from the CAD CoP stated that "*I guess it is primarily because the work that we do does not overlap. She's in the rail group and was working in microstation, which I do not use. So there would be no benefit to me trying to get knowledge from her."* In this case, Davidson perceives that his connection will not have any useful knowledge to share with him due to a complete lack of overlap. With complementary connections, there is very little overlap, but both knowledge bases are required to perform a more complex task. Here, we see that non-overlapping connections do not have any sort of useful commonality. Marcus in the Transportation CoP talked about his frustrations in dealing with another professional that has a non overlapping connection in terms of geographic specificity. He recalls that "*with Lindsay there is less overlap in what we are doing. She has been focused on geographically specific technical projects. I have gone to her with several issues, but there is a disconnect in terms of her focus and mine. It's partly geographical, and partly because her projects are so theoretically based that they haven't had a direct relevance to my work."*

Non-overlapping connections do not appear to provide any sort of useful coordination between specialists in the CoP. Rather, professionals spend time that would otherwise be productive interacting with somebody who cannot satisfy their knowledge based needs. Although rare, we observed several non-overlapping connections in each of the broadly focused CoPs.

CoPs AND SOCIAL NETWORKS

Each of the three CoPs contained a diverse mix of overlapping, complementary, growth, and non-overlapping connections. As we described in the previous section, different types of connection facilitate

different types of coordination between knowledge specialists. From this evidence, we draw two primary observations to help understand how CoPs coordinate specialist knowledge. First, CoPs provide a flexible environment where several types of connection and multiple forms of coordination are possible. Secondly, there is a very low incidence of non-overlapping connections that do not usefully coordinate specialist knowledge. These findings have a profound impact on our understanding of the structure of social networks in CoPs, and how they work to integrate a wide variety of different knowledge bases. These impacts and the resulting implications for project based organizations are discussed.

For most professionals, searching for knowledge resources is often inseparable from the peer to peer social networks that comprise CoPs (Borgatti and Cross 2003). The social networks cultivated within global CoPs facilitate a "who knows who" culture that increases the different knowledge bases that people are aware of, therefore increasing their location and access to different people as knowledge resources. Higher visibility, allows people to swiftly locate others, gain personal introductions, and gain the marginal benefits of belonging to a community, while creating "structural holes" to different areas of the company (Burt 1992). A sense of belonging can activate many social motivators to share knowledge such as reciprocity (Javernick-Will 2012), where members feel the need to contribute because they have received knowledge from others. While social networks have always been considered a vital component of CoPs (Brown and Duguid 1991; Lave and Wenger 1991), there has been relatively little work regarding the different types of relationships that comprise these networks. Within this setting, understanding the different types of coordination and degrees of overlap in professional knowledge is vital to understanding how these communities operate.

Robust social networks in distributed CoPs need a diverse array of overlapping, complementary, and growth connections to create a cohesive awareness of who knows what. Each type of connection plays an important role in the network, and facilitates different types of coordination. Groups of specialists with overlapping connection are the locus of technical innovation and determine the standard of technical practice within the company. To these pools of expertise, complementary connections can link these dispersed knowledge bases through productive inquiry. Say that a geotechnical engineer has a question about bridge abutment design, and approaches a structural engineer who specializes in building design. Even though the structural engineer may not be able to answer that question, he is able to identify the subtle differences of expertise among his/her colleagues and to select the best person or resource to apply to a knowledge based need. Within pools of overlapping connections, growth connections serve to replenish knowledge stocks by passing knowledge from experts to less experienced workers, multiplying the number of people who have capabilities within a given field (Lave and Wenger 1991).

We may also suppose that social networks act as a mechanism to increase the efficiency of CoPs by isolating and removing non-overlapping connections from the community. When CoP members become connected to other employees that do not have a relevant knowledge to their field of practice, they will not interact with them, not recommend them, and therefore gradually eliminate peer connections to that irrelevant knowledge base. Key to this process, however, is that CoP members have a somewhat cohesive view of the knowledge domain contained within the CoP. If the membership of a CoP is too broad, the result will be fragmented networks consisting of clusters of non-overlapping knowledge bases, because there will not be a mutually applicable task to link the dispersed specialist knowledge.

IMPLICATIONS AND FUTURE WORK

Within construction and engineering organizations, managers struggle to ensure that relevant expertise is available when and where it is needed for project work. Fragmentation within organizations

leads to repeated mistakes on projects, and dedicating resources to problems that have been solved elsewhere in the organization. At the same time, when knowledge is shared equitably throughout the company, it is possible to increase global consistency of practice, facilitate innovation, and boost performance (Cross and Cummings 2004). Although CoPs have emerged as one way for managers to facilitate knowledge sharing within project based organizations (Roberts 2006), there is little empirical evidence of the types of coordination which occur in these CoPs. This study daylights the inner workings of dispersed, multi-disciplinary CoPs through studying the informal knowledge sharing networks that comprise CoPs. Because the broad, topical boundaries of CoPs outline a knowledge base that is too large to be comprehended by any single, overseeing mind (Lindkvist 2005), we must understand the types of coordination between knowledge workers as dependent on the degree of overlap in their knowledge bases. This has two practical impacts.

First, as managers define the topical boundaries of CoPs, the epistemological boundaries affect the strategic purpose the CoP. As an example, narrowly focused CoPs (i.e. Fungal growth in wastewater treatment plant clarifiers CoP) will have an increasing proportion of overlapping connections, and the primary types of coordination that occur will be problem solving, sensemaking, and the identification of subtle expertise. Furthermore, within narrowly focused CoPs, it should be relatively simple to locate somebody with relevant expertise to a particular project or problem. On the other hand, broadly focused CoPs (i.e. Transportation CoP), will have overlapping, complementary, growth, and non-overlapping connections, meaning that many different types of knowledge coordination are possible. At the same time, it would be more difficult to locate someone with knowledge relevant to a specific problem or project. This has the practical implication that managers can exert strategic control over CoPs by influencing their topical boundaries, and create a portfolio of CoPs that address different, but complementary strategic concerns. For instance, narrowly focused CoPs can effectively drive consistency in technical practice by efficiently facilitating knowledge sharing between global experts. Then, through broadly focused CoPs, managers can reduce coordination problems between disciplines through broadly focused CoPs, or encourage innovation through the cross pollination of ideas.

Secondly, by typifying coordination in terms of overlapping, complementary, and growth connections, we have provided a framework for managers to understand the basic structure of social networks. With this knowledge, managers can create targeted management interventions to create different types of connections. On a micro level, individual connections will have different characteristics and abilities to transfer knowledge based on whether they are overlapping, complementary, or growth types of connection. By highlighting and profiling areas of expertise within the company, managers may be able to bridge relevant pockets of expertise to bring global practice leaders together, or to connect different areas of expertise. As Borgatti and Cross (2003) discuss, professionals will not seek knowledge from someone if they do not know what that person knows. Within broadly focused CoPs, most people will not know the full extent (even on a topical level) of the other areas of expertise that are represented within the community. In some cases, bringing professionals together for webinars, face-to-face conferences, or even highlighting different groups of experts in a newsletter will increase their ability to locate and utilize others as knowledge resources. In contrast, as managers look to pass down the knowledge accumulated by older generations before they retire, replication of knowledge resources corresponds to a growth type connection. These would occur most strongly in smaller, more intimate CoPs where younger professionals can learn through participating in a social community (Lave and Wenger 1991), rather than just being given access to experts.

To strengthen social networks, prior scholarship demonstrated that managers can create connections between employees that span geographic or organizational boundaries through a variety of management techniques (Cross et al. 2010). Similarly, overlapping, complementary, and growth connections should be deliberately targeted to increase the efficacy of social networks. This means that managers should encourage the conglomeration of overlapping experts, interspersed with growth connections, and then unite these dispersed knowledge bases through complementary connections that are linked by project tasks. Although connections are frequently initiated through project tasks, the relationships established can endure beyond these project assignments, implying that strategic creation of project teams can also facilitate network connections. On a theoretical basis, understanding the types of knowledge coordination occurring in CoPs provides a rich foundation for future work. A practice based view of project organizations shows that they are not only fragmented in terms of projects, but also by epistemological practice (Brown and Duguid 2001). If this is the case, then project organizations ought to be viewed as communities of communities (Brown and Duguid 1991), in which the chief aim of the organization is dynamically coordinating knowledge between these communities (Brown and Duguid 2001). Future work could evaluate the relative benefits of each type of coordination to the organization, or study the synergistic effects of different degrees of overlap in social networks. Quantitative studies could perform social network analysis on networks and overlay the degree of overlap to see if boundary spanners tend to have a certain type of connection, and explore how this affects knowledge flows within social networks. From this study, there are a number of concepts that could be empirically verified. It would be simple, yet theoretically valuable to test the different types of connection and coordination occurring in broad and narrow communities.

CONCLUSIONS

As with any study, there are inherent limitations to the scope and application of this work. To begin, we must be careful with the application of these findings do different contexts. The external validity of the study is limited by convenience based selection of CoPs, and the lack of consensus among industry leaders in managing and defining CoPs. Although the researchers were careful to select three CoPs that were globally distributed, multi-disciplinary, supported by online infrastructure, and initiated by managers, there are external factors that were still difficult to control. Because our three CoPs came from two different organizations, there are different management cultures, geographies, and histories that created discrepancies in the communities. This was partially remedied by examining dyadic level connections, and consistently finding overlapping, complementary, growth, and non-overlapping connections in each CoP. Furthermore, both companies do project based work in the engineering and construction industry. Because of this, we must acknowledge that the application of these findings outside of project based industries is unknown.

A second limitation occurs from a methodological standpoint. Due to the exploratory nature of this study, data collection was not initially targeted to verify our final findings. Through inter-coder reliability and following the qualitative analysis processes outlined by (Haney et al. 1998), our results are as robust as possible in terms of construct and internal validity, yet there is always more to be desired. Future work verifying the association of particular types of coordination to different types of connection would be welcomed.

Although project based organizations have embraced communities of practice as a means to manage knowledge, these CoPs deviate in form and function from their theoretical roots. Although the business goals of CoPs align very closely with the knowledge based view of the firm, there is not theory

as to how CoPs coordinate the knowledge of specialists. This paper uses qualitative methods to explore the different types of coordination happening with three global CoPs, and describes how the degree of overlap between specialists' knowledge bases affects the type of coordination that can occur. The result is a robust, practical framework for understanding the composition of social networks in distributed CoPs.

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