A Social Network Analysis of a Virtual Community of Practice

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This paper investigates the relationship between the structural characteristics of a virtual CoP and the measures of social network analysis. Several implications were developed by the results of the study First, the study, based on reviews of both the CoP and SNA literature, identified specific structural measures of SNA; connectedness, geodesic distance, and density. Second, the formal CoP investigated in this study showed greater development that the classic, informal CoP in terms of the structural dimension of a CoP. The results show that those measures of social network analysis provide an illuminating way to better understand the structural properties of CoP's. Implications of the study with some suggestions for future research are provided.

Keywords : community of practice, social network analysis, density, connectedness, geodesic distance

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Introduction

A CoP is defined as a group of people, informally and contextually bound in a work situation, who are applying a common competence in the pursuit of a common enterprise, and who deepen their knowledge and expertise in this by interacting on an ongoing basis (Brown & Duguid, 2001; Lave & Wenger, 1991; Wenger, 1998). This rather broad definition implies two definitional characteristics of a CoP; 1) emergent and informal relationship, and 2) direct and strong "ties" among members. Further, Wenger(1998) suggests that a CoP is composed of two dimensions: the communication dimension and the structural dimension. Thus, to understand the phenomena of a CoP systematically, we need to have relevant and practical research methods that could investigate those definitional characteristics of the two dimensions of a CoP.

Recently, the field of CoP research and practice is experiencing major changes and facing new challenges thereof. Researchers and practitioners claim that a CoP can be; 1) the result of a management initiated rather than being emergent (Wenger et al, 2002), and 2) virtual rather than involving face-to-face interactions (Allatta, 2003). These two new phenomena of contemporary CoP's do not seem compatible with those Lave and Wenger initially suggested in their early writings.

In regard to management initiation, more CoP's are planned, initiated, and nurtured by the organizations. CoP's have received considerable attention as strategically important to organizations because they are thought to be repositories for knowledge, its maintenance, reproduction, and extension(Brown & Duguid, 2001; Wenger et al., 2002). Therefore, it seems natural that the management of organizations would try to initiate the birth of and facilitate the development of their CoP's for their competitiveness. However, it is unclear if what conditions CoP's can be created. Wenger(1998) argues that learning cannot be designed and organizations cannot create CoP's. They can only create the organizational and technical structures that may facilitate a CoP. The community emerges as members

react to that structure and try to understand and make sense of their environment. Also practice is not predetermined by the intended design, either: it instead emerges as members respond to it. Efforts to create a CoP may unintentionally hurt it. The theoretical underpinnings of the original Cop seem conflicting with the practical needs of competitiveness-seeking organizations.

Another theoretical issue involved in CoP research is the expansion of virtuality in a CoP; changing from analog, face-to-face interactions to technologically-mediated, distributed properties that are mainly due to the ICT technologies. The wide spread and use of information technology in workplace and life world has brought technologically-mediated interactions as primary links that bond the members of the CoP's (Brown & Duguid, 2000). Recently, Brown and Duguid, major contributors to the CoP literature, introduced the term 'Network of Practice (NoP)' based on their works of the CoP. NoPs range from face-to-face communities of practice to electronic networks of practice, often referred to as virtual communities (Brown & Duguid, 2001; Cross, Parker & Borgatti, 2002). The conceptions of the NoP may help us to theoretically understand the phenomena of sharing and creating knowledge in a network of practice situated in a virtual space.

The two issues above mentioned also brought a methodological issue. Until recently, CoP studies largely depend on rich ethnographic accounts that have provided deep views of a small sized CoP. As in Orr's (1996) work about copy machine service technicians, the ethnographic approach has been regarded as "the" method that could identify and thickly describe the CoP's. Problem is, in this approach, we could have a good view from a communication dimension, but could have lost the structural dimension of CoP's in larger organizational settings. Also, if labor-intensive ethnographic approach monopolizes the emerging phenomena of a CoP, the researchers could have lost the huge and easy-to-collect electronically transactional data created by the CoP members in a prompt way. Therefore, for today's CoP researchers that want to take advantage of capturing non-visible (electronic) communication that is prevalent in today's business organizations

(Allatta, 2003) and school settings (Dietz-Uhler & Bishop-Clark, 2001), it is necessary to be equipped with new, technology-utilizing research methods, such as SNA (Social Network Analysis). SNA would allow us to focus on the structural dimension of contemporary virtualized CoP's with less research time and labor involved (Cross et al, 2002).

The purpose of the study is twofold: 1) to develop the possible theoretical relationship between the structural properties of CoP's and the relevant measures of Social Network Analysis, and 2) to empirically observe the structural characteristics of a formal, or a management-supported CoP in a virtual business in Korea using the proposed SNA measures and compare those to those of informal CoP. By identifying and specifying structural properties of a CoP, the study may open the door for additional theorizing on both the structural and communicative aspects of CoP's as well as for further empirical studies.

Review of the Literature

Community of Practice

Lave and Wenger (1991) coined the term, Community of Practice (CoP) in their book about learning. Specifically they emphasized the social aspects of learning. They argue that learning is intimately tied to social practice and that learning through apprenticeship occurs via legitimate peripheral participation. Learners begin as peripheral participants of a CoP. Over time the learners acquire knowledge and cultures, and they become recognized by other members as possessing the appropriate knowledge as core members. Then, the newly recognized members could work with others to perform their jobs and solve problems.

The phenomena of CoP's are easily observed among business organizations. In a business organization that pursues clearly set and shared goals, employees work

together for a common enterprise and, in the process, build relationships, share information, and learn practical knowledge and skills. This is why Wenger has dedicated to fully develop the CoP constructs especially in business settings (Wenger et al, 2002).

As a matter of fact, the business situation can be seen as one of the richest environments that create the context for the process of negotiating a common enterprise (Wenger, 1998), the core concept of the CoP. During the negotiation process, employees or members of a CoP engage in three processes based on the communication dimension: narration, collaboration, and social construction (Brown & Duguid, 2001). Through the narration of stories, employees help each other to make sense of ambiguous, problematic situations and, in the context, non-canonical practice is exercised (Brown & Duguid, 2001). The second aspect of CoP's is the collaboration that occurs among its members. With knowledge-intensive tasks, often no individual can solve the problem on her own 'bounded rationality' (Simon, 1990) due to the lack of required expertise and of tools that mediate actions. The third process, social construction, occurs through the mutual engagement of the members of a CoP. In this process, the members develop a shared repertoire consisting of both the tacit and explicit means of communication (Polanyi, 1966). As noted earlier, participation is a prime characteristic of a CoP, and is an inherently social activity. This communication dimension can effectively be examined by ethnographic methods.

In addition to the communication dimension, a CoP has a structural dimension. Wenger (1998) discusses a number of structural indicators to find a CoP was formed; 1) shared discourse, 2) rapid flow of information, 3) sustained and direct mutual relationship. The structural dimension cannot be easily observed by the ethnographic method which is mainly focused on individual, microscopic level of CoP phenomena (Wasko & Faraj, 2005). I argue that ICT log information, if analyzed by relevant social network analysis measures, can be used as a powerful alternative research method that investigates Wenger's structural indicators of a

CoP.

Now, it is time to review those relevant social network analysis measures that may indicate the formation and the transformation of a CoP in terms of its structural properties. Given the social nature of a CoP and the prevalence of new communication technologies in today's workplace, there is a rationale for the heavy emphasis on the use of social network techniques applied to ICT log data such as email (Allatta, 2003; Schenkel et al, 2001).

Social Network Analysis

Basic Concepts of the Social Network Analysis

A social network has been defined as "a specific set of linkages among a defined set of persons" (Wasserman & Faust, 1994:2). The fundamental principle in a social network is that pair-wise relationships among individuals link to form networks whose structural characteristics are both the result of dynamic processes, and affect group and individual outcomes (Scott, 2001). Social network analysis (SNA) provides a rich and systematic means of assessing networks by mapping and analyzing relationships among people, teams, and even entire organizations (Cross et al, 2006).

This framework of analysis views social relationships in terms of nodes and ties. Nodes are the individual actors within the networks and ties are the relationships between the actors. There can be many kinds of ties between the nodes. Sending emails, sharing war-stories, and collaborating in a virtual workspace are a few examples of such ties.

SNA as an analytic method includes a variety of quantitative indices. These indices can be categorized into two levels; individual and network (Schenkel et al, 2001).

Two Levels of SNA measures

At the individual level, the notion is that a person's position in the network provides both constraints and opportunities for the individual. For example, an employee, though very intelligent and productive, may not play a vital role if she is socially isolated by her colleagues. At this level of understanding, several studies have found social network analysis to be a powerful approach for understanding how an individual's position in a social network influences a wide range of outcomes such as learners' school achievement (Dietz-Uhler & Bishop-Clark, 2001), cognitive and affective learning in a blended learning situation (Jo, 2007), and knowledge creation (Papa & Tracy, 1988). Among many social network measures, degree centrality, the number of ties to other members in the network, have been widely used in the above-mentioned studies. For example, an employee with high degree centrality has more opportunities and alternatives than other actors in her virtual team (Dietz-Uhler & Bishop-Clark, 2001).

At the network level, there is the holistic notion that suggests some structural properties and outcomes of a social network are a function of its complete structure and are not reducible to either an individual actor or a single link (Wasserman & Faust, 1994). The key feature of these diagrams lies within the pattern of relationships displayed and the relative position of individuals to each other (Kim & Kang, 2004). Therefore, visualizing a structural properties of a network helps learners in a collaborative learning situation identify the global structure of the team and identify their status of knowledge-sharing activities (Lipponen, Rahikainen, Lallimo & Hakkarainen, 2003).

Among many network level SNA measures, connectedness, geodesic distance, and density are most relevant to the analyses of virtual CoP's (Allatta, 2003; Schenkel et al, 2001). Connectedness measures the degree of mutual engagement of the member and is defined as the maximal set of individuals who are directly or indirectly reachable to each other in a network (Harary, 1969). Geodesic distance measures the number of links in the shortest path connecting actors in the network

(Wasserman & Faust, 1994). Density represents degree of cohesion in the group, and is defined as the total number of ties divided by the total number of possible ties in the network (Wasserman & Faust, 1994).

With regard to the possible connection between CoP's and SNA measures, Wenger has noted that a CoP can be viewed as a network with nodes of "strong" ties (Wenger, 1998:74, 126). However, he distinguished the two notions clearly: "A community of practice is not defined merely by who knows whom or who talks with whom in a network of interpersonal relations…What is of interest to me is…the nature of *interpersonal relationships through which information flows* as the nature of what is shared and learned and becomes a source of cohesion – that is the structure and content of practice" (ibid: 72, 21. italicized added by the researcher). Thus, what distinguishes a CoP from plain networks, according to Wenger, is that a CoP is a contextually based network consisting of individuals who are involved in a common enterprise, and sharing information interpersonally. In sum, every CoP consists of a network, but not every network is a CoP. If we agree with this notion, then the questions rise whether there are specific structural properties that are likely to distinguish a CoP from other plain networks.

CoP-relevant SNA measures

There are quite many SNA measures that are known as indicating different aspects of a variety of networks. In regard to CoP's, three SNA measures - connectedness, geodesic distance, and density - seem corresponding to the three indictors of the presence and development of a CoP - shared discourse, rapid flow of information, and sustained and direct mutual relationship, respectively.

Connectedness

Perhaps the most fundamental aspect of a CoP is the mutual engagement (Wenger, 1998). Through engagement, individuals participate in each of the three

communication dimension processes: narration, collaboration, and social construction that form the core of a CoP practice. The result of this interaction is a complex network of social relations and interdependency (Granovetter, 1983).

Thus, the extent to which members of a network are connected via pair-wise interaction ties is an index of the extent to which the network members can 'potentially' function as a CoP. Therefore, a minimum structural characteristic of a CoP is that every member should be 'reachable.' If there is a path between two nodes or members then they are said to be reachable. In other words, all members of the network are directly or indirectly connected with each other and there should be no isolated members.

In social network analysis, the maximal set of individuals who are directly or indirectly reachable to each other in a network is called a 'connected component' or simply connectedness (Harary, 1969). Therefore, a CoP is necessarily located wholly within a single connected component. This then lead the researcher to the first hypothesis:

Hypothesis # 1: Connectedness: In a formal CoP, compared to an informal CoP, more members are connected, directly or indirectly.

Geodesic Distance

Another fundamental characteristic of a CoP is the notion of shared repertoire (Wenger, 1998). The geodesic (or shortest) distance between two nodes is defined as the number of links in the shortest path connecting them. Thus, the greater the geodesic distances between pairs of group members, the longer it takes for information to flow from one to the other, and the greater the likelihood that what is transmitted arrives too late or fails to arrive at all to the target node or member. Therefore, the researcher could establish Hypothesis #2 as follows;

Hypothesis # 2: Geodesic distance: In a formal CoP, compared to an informal CoP, a shorter average geodesic distances will be observed.

Density

Through mutual engagement and the associated communication processes, the practices of a community is disseminated and developed. Connectedness is a necessary condition for the development but not sufficient since a certain level of density in a network should be achieved to become a fully developed CoP. Geodesic distance represents the efficiency of the dissemination and sharing of the information and knowledge in a CoP but not the degree of directedness in the efficient network.

The third indicator, density of a network, measures degree of cohesion in the group, and is defined as the total number of ties divided by the total number of possible ties in the network. A dense network consists of actors who are "directly" connected to each other, rather than connected through agents. A CoP should show a higher density than a less developed CoP. Density positively correlates with geodesic distance but emphasizes directedness of the links.

Hypothesis 3: Density: In a formal CoP, compared to an informal CoP, greater density of ties will be observed.

Procedure

Participants and Experimental Conditions

To investigate the hypotheses set above, the researcher conducted an empirical test with email transactions data among 35 software developers of Company K. Company K, a high-tech PMP (Portable Media Player) manufacturer in Korea, has been spun off from the mother Company J in December 2007. The Company J, one of the major internet shopping mall developers in Korea, recently decided to expand their business into PMP software development market. The 35 participating

software developers that were members of an informal study group in Company J volunteered to join the newly established Company K. In other words, the informal study group of Company J had transformed into the formal business organization, the Company K.

When the members were working for Company J, they were members of an informal study group, whose name was "the Mobilia". The unique characteristics of the group was its viarutality. Its members were from geographically distributed places including three countries in the Asia Pacific region. Among the 35, 30 were Koreans and 5 were from foreign countries such as Singapore, Taiwan, and China. All of them have college degrees or higher and have a good command of English. Their mission is to conduct collaborative research on wireless communication technology and to develop software for the company's state-of-the-art PMP software. Most of them have never met face-to-face before the present study. The subject matter they investigated collaboratively was the mobile communication and encryption technologies. However, as focus group interview conducted by the researcher indicates, their shared goals were focused only on learning and socialization but not on creating business values. The members met quite regularly – once a month – but no established norms or regulations were imposed members' mandatory participations to the meetings. Therefore, the researcher could presume they were members of a CoP that had emerged in an informal setting.

After the spin-off from the mother company J in late December, 2007, the members of the community turned out to become employees of profit-seeking business, Company K. Since then, the CEO of Company K decided to support and to manage the informal community activities, and established research goals and regulations for the member employees. Meeting schedules and incentives policies as well as management-supported research goals were established in early January, 2008. Now, a formal CoP was born.

Research Design

This study employed a one-group pretest-posttest design. In this design, a single group is measured not only after being exposed to a treatment of some sort, but also before. In the present study, the treatment was the spin-off of the Company J. Before the treatment, the 35 participants were members of informal CoP. After the treatment, they became members of a formal CoP.

$$O_1 \qquad X \qquad O_2$$

Figure 1. Research design diagram

Data Collection

The email transactions logs collected for two months from November through December 2007 served as data for the informal CoP condition whereas those collected for the two months after the spin-off represented the formal CoP condition. The email logs that are used as data for the study are advantageous for a number of reasons. First they do not suffer from low survey response rate. Second, the data are automatically collected and stored with very low cost. Third, the non-obtrusive data provide information not on the subjective response but on the authentic behavior of the subjects.

The data included the date, time, sender, and receiver(s). Then the data was transformed into square matrix, or an adjacency matrix, with directional frequency values. The only extra work involved in the study was in transforming the text-based log files into matrix data format. The contents of the email were not be analyzed since they are not necessary in SNA procedure and may even infringe participating employees' privacy.

Then, the three SNA measures, connectedness, geodesic distance, and density were calculated to test the three suggested hypotheses respectively. NetMiner 2.6

Professional software package was used to compute the SNA measures. Most commonly used inferential statistics procedures, such as t-test, that require the independence of observations could not be employed for the analyses of those mutually relational data in the study. Therefore, only descriptive analyses could be conducted to test proposed hypotheses.

Results

Based on the data extracted from email logs, the three proposed hypotheses were tested. The results are;

Hypothesis 1, "In a formal CoP, compared to an informal CoP, more members will be connected, directly or indirectly, to every other members," was confirmed by the data. The connectedness measures increased 0.662 to 1.000, which is the maximum degree possible, and means no individual remained isolated. Therefore, after the spin-off, the members of the CoP could access to each other directly or indirectly, and each member's knowledge and skills could be shared in the network by any means.

Hypothesis 2, "In a formal CoP, compared to an informal CoP, the average geodesic distances among all possible pairs will be shorter," was also confirmed by the data. The geodesic distance shrank from 3.074 to 1.552, which means more members could reach other members directly. On average, pairs of an member's email addressed were 1.552 geodesic distance from each other, which is significantly shorter than an average of 3.074 for randomly chosen email pairs. This indicates that pairs of email communications which correspond to the same entity occur within relatively close proximity of each other.

Hypothesis 3, "In a formal CoP, compared to an informal CoP, density of ties will be greater," was also confirmed. Density represents degree of the cohesion in the community, and is defined as the total number of ties divided by the total

number of possible ties in the network (Wasserman & Faust, 1994).

The results of the analysis are summarized at the Table 1 below.

In sum, the formal CoP showed greater level of development than the classic, informal CoP in terms of the structural dimension of CoP.

Table 1. Results of the Hypotheses Testing

	Hypotheses	Observed Results		Confirmation
		Informal CoP	Formal CoP	
#1	Connectedness will INCREASE	0.662	1.000	Y
#2	Geodesic Distance will DECREASE	3.074	1.552	Y
#3	Density will INCREASE	0.175	0.489	Y

Conclusion

Wenger (1998) argues, that learning cannot be designed and organizations cannot create CoP's. Yet many organizations understand the strategic importance of CoP's and are trying to create them. Especially in the Human Performance Technology (HPT) field that emphasized non-training intervention for the improvement of organizational performance improvement, the idea of intentional creation and facilitation of CoP's should be a very attractive and fresh approach (Cross et al, 2006; Massey et al, 2005).

The study, based on reviews of both the CoP and SNA literature, identified specific structural measures of SNA; connectedness, geodesic distance, and density. These measures are considered to represent the nature and characteristics of the structural dimension of a CoP. Second, the formal CoP investigated in this study showed greater development that the classic, informal CoP in terms of the structural dimension of a CoP. The results show that those measures of social network analysis provide an illuminating way to better understand the structural

properties of CoP's. Implications of the study with some suggestions for future research are provided.

The findings suggest that social network measures and diagrams should serve as effective facilitators for the development of emerging virtual CoPs. We cannot create CoPs. However, with relevant and careful enablers such as SNA diagrams, we may create effective interventions for CoPs.

However, there are some delimitations that should be addressed. First, three-month period may not be enough to detect the possible developmental stages of a management-supported or formal CoP. Second, the research excluded the face-to-face dimension of activities among the members.

Several research issues that are deserved to be investigated in the future are suggested:

First, more advanced SNA measures should be tested for their validities as measures for CoP's. For example, core-periphery measure (Borgatti & Everett., 1999) seems to be a good indicator to trace the status of a member in the trajectory from periphery to core (Allatta, 2003).

Second, since the focus of the study was on the structural dimensions, the researcher has not taken into consideration any of the communication dimensions of CoP's when conducting analyses. A potential weakness in structural approaches is that the qualities f the relationships that are mapped are ot fully considered. Further research should look at the interaction between the structural and communication dimensions of CoP's and, further, their relationship with organizational performance.

Third, studies that are tracing the historical changes in a CoP observed by the SNA measures, such as the transition of a member from a peripheral to core position, are to be conducted to facilitate our understanding of the formal development of a CoP.

Lastly, major attribute variables of CoP's, such as membership of department, gender, education, and work experience, may be included to investigate interactional effects of structural measures of CoP's and those variables.

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