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## Social networks, communication styles, and learning performance in a CSCL community

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### Abstract

The aim of this study is to empirically investigate the relationships between communication styles, social networks, and learning performance in a computer-supported collaborative learning (CSCL) community. Using social network analysis (SNA) and longitudinal survey data, we analyzed how 31 distributed learners developed collaborative learning social networks, when they had work together on the design of aerospace systems using online collaboration tools. The results showed that both individual and structural factors (i.e., communication styles and a pre-existing friendship network) significantly affected the way the learners developed collaborative learning social networks. More specifically, learners who possessed high willingness to communicate (WTC) or occupied initially peripheral network positions were more likely to explore new network linkages. We also found that the resultant social network properties significantly influenced learners' performance to the extent that central actors in the emergent collaborative social network tended to get

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higher final grades. The study suggests that communication and social networks should be central elements in a distributed learning environment. We also propose that the addition of personality theory (operationalized here as communication styles) to structural analysis (SNA) contributes to an enhanced picture of how distributed learners build their social and intellectual capital in the context of CSCL.

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**Keywords:** Computer-mediated communication; Cooperative/collaborative learning; Distance education and tele-learning; Distributed learning environment; Social network analysis

## 1. Introduction

A growing body of research has demonstrated that a social network is a central element in collaborative learning environments (Harasim, Hiltz, Teles, & Turoff, 1995; Haythornthwaite, 2002). From the social network perspective, learning is a social and collective outcome achieved through seamless conversations, shared practices, and networks of social connections (Brown & Duguid, 1991). Knowledge, in this sense, is not a static object acquired by an atomic individual but is actively co-constructed through ongoing social exchanges and collaborations among multiple learners embedded in social networks (Cohen & Prusak, 2001; Lave & Wenger, 1991; Nonaka & Konno, 1998). Social networks also play instrumental roles in learning environments as a major conduit of resource and knowledge exchanges (Cho, Stefanone, & Gay, 2002) and as a source of social support and socialization for distributed learners (Haythornthwaite, 2002). Hence, the way individuals create social capital – or the way they are situated in social networks from the structuralist point of view – should significantly influence the acquisition, construction, and exchange of knowledge.

Theoretically, there are abundant discussions emphasizing the value and the impact of social networks in the studies of organizational learning (Nahapiet & Ghoshal, 1998), knowledge management (Cohen & Prusak, 2001), and distance learning (Haythornthwaite, 2002). Empirically, however, very few studies have actually examined the “origins” or “outcomes” of social networks in actual Computer-Supported Collaborative Learning (CSCL) or Cooperative Work (CSCW) settings (Millen, Fontaine, & Muller, 2002; Woodruff, 2002). In other words, relatively little research has been conducted to explicitly examine what factors influence the creation of different social networks, why some learners occupy structurally advantageous positions than others, or how such emergent network properties, i.e. structural elements in a learning community, influence learning performance and outcomes in CSCL/CSCW settings.

The aim of this study is (1) to explore the way distributed learners develop and sustain collaborative learning social networks when they engage in CSCL/CSCW activities, (2) to identify structural and individual factors that influence the way people develop emergent collaborative social and collaborative structures, and (3) to test the degree to which the resultant social network properties influence learning outcomes related to CSCL practices. We conducted a field experiment in which 31 college engineering students from two distant universities collaborated on the design of aerospace systems using online collaboration tools for two academic semesters. First, using social network analysis and longitudinal survey data, we analyzed the development of collaborative learning social networks over time. Second, we identified communication styles (CS) and a pre-existing friendship network as the individual- and structural-level factors, respectively, and tested the degree to which the two

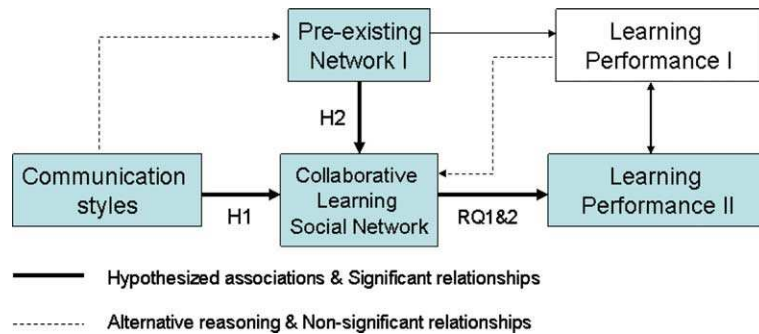


Fig. 1. Research model and results.

antecedents influenced the structure of collaborative learning social networks. Third, we examined the extent to which the emergent social network variables affected learning outcomes, as measured by learners' performance (see Fig. 1 for a visual description of our research model). Finally, the paper concludes with a discussion of findings and implications for future research with a special focus on collaborative learning and social network studies. Given the centrality of a social network as a vehicle for knowledge creation and learning (Brown & Duguid, 1991; Lave & Wenger, 1991), it is believed that findings of this study will allow us to model with greater precision, the processes of collaboration and learning in Computer-Mediated Environments (CMEs).

## 2. Literature review

### 2.1. Communication styles and willingness to communicate

Communication scholars have long held the idea that individuals exhibit personality-like differences in their basic communication styles. As a result, researchers have developed a number of communication style/competence indices such as management communication style (MCS) (Richmond, 1979), willingness to communicate (WTC) (McCroskey, 1987, 1997), multivariate communication style (MCS) (Norton, 1978), and interpersonal communication competency scale (ICCS) (Rubin & Martin, 1994). The current study focuses on the WTC and its effects on collaborative learning social networks, given that this particular construct has been validated in various contexts (Richmond & Roach, 1992) and deemed to be most relevant to our study purpose.

WTC is defined as the degree to which an individual is inclined to initiate communication with different people (friends, acquaintances, and strangers) in various social settings (interpersonal, group, and large meetings) (McCroskey, 1997).<sup>4</sup> It is shown that individuals display consistent

<sup>4</sup> Some argue that this measure is similar to introvert and extrovert personality types commonly found in personality measurement schemes such as Myers–Briggs Type Indicator (MBTI) (Myers, 1984). Others argue that it is not conceptually separated from other communication style or personality measures such as communication apprehension, reticence, shyness (Kelly, 1982). However, Richmond argues that WTC is different from others since it measures behavioral intention to communicate which can be caused by many factors such as CA, shyness, trait-based personality, or situational factors. Anyway, this focus of this study is not on examining construct validity of communication styles or personality types. Therefore, we decided to use this scale for this study.

behavioral tendencies when they communicate with real or anticipated communication partners (McCroskey, 1987; Richmond & Roach, 1992). A high WTC individual feels more comfortable with initiating, continuing, and strengthening social relationships with new communication partners whereas a low WTC individual tends to be reluctant or less apt to communicate with others (McCroskey, 1987). Conceptualized as the Behavioral Intention (BI) component in the Theory of Reasoned Action (TRA) (Fishbein & Azjen, 1975), WTC has been reported to be a strong indicator of communication behaviors in social life, small groups, and organizations (Richmond & Roach, 1992). For instance, high WTC than low WTC people are more likely to develop heterogeneous relationships in organizations and to explore and initiate new relationships when participating in new social environments. Consequently, high WTC persons tend to occupy more leadership positions or achieve better performance (Richmond & Roach, 1992), whereas low WTC persons tend to be less successful in organizational positions where much communication is expected of them (Richmond & McCroskey, 1989).

## 2.2. Communication styles and collaborative learning social network

Only a few studies have examined how individuals' characteristics such as communication styles affect the ways in which people create and sustain their social/communication networks. The structural approach to social dynamics in social network analysis (SNA) tends to over-emphasize the structural determination of human behavior, but has neglected the possibility that network positions occupied by individuals might be influenced by their psychology (Kilduff, 1992). As Burt (1986) noted, individual dispositions have often been dismissed as "the spuriously significant attributes of people temporarily occupying particular positions in social structure" (p. 106).

While there have been investigations of the "origins" of network positions from a cultural or dispositional perspective (e.g., Emirbayer & Goodwin, 1994; Kilduff, 1992), others, however, began to investigate the impacts of individual characteristics on the structure of larger social systems. For instance, previous studies showed that different personality types were associated with distinctive network positions (Burt, Jannotta, & Mahoney, 1998) and influenced the way individuals leveraged their network positions in organizations (Mehra, Kilduff, & Brass, 2001). More specifically, individuals with high entrepreneurial personality occupied more entrepreneurial network positions such as brokerage positions (Burt et al., 1998), and those who had high self-monitoring personality were more inclined to leverage their central network positions to perform better in an organization (Mehra et al., 2001).

While increasingly more attention has been paid to examining the micro-foundations of social networks in *organizational* settings, there is little work examining the "origins" or "antecedents" of collaborative social networks in *educational* settings. This is surprising, as "individual differences" have long been a central variable in educational research (Ellis, 2003; Scalia & Sackmary, 1996; Webb & Palinscar, 1996). In this study, we identify communication styles (i.e., WTC) as a critical factor influencing the way distributed learners develop collaborative learning social networks in a CSCL setting. Learning in a CSCL setting is deeply based on communicative acts such as conversation, collaboration, and social exchanges (Harasim et al., 1995). Further, interactions in such learning environment are often remote, faceless, uncertain, and mediated by newer computer-mediated communication (CMC) systems (Haythornthwaite, 2002). Hence, individuals' disposition toward communication (i.e., willingness to communicate) should significantly affect

learners' behaviors, especially how they build new social and learning relationships/networks with distributed, remote learning partners, who are often strangers.

While there is no direct evidence on how communication styles influence the structure of a larger social system, previous studies provide meaningful support for the contentions of this study. For instance, studies on CSCL show that individual learners display varying degrees of inclination toward group work, collaborative technology, and cooperative learning environments (Hiltz, 1994; Witmer, 1998), which, in turn, significantly influence the way they use instructional technology (Scalia & Sackmary, 1996) and their learning performance (Webb & Palinscar, 1996). As noted above, recent SNA studies have observed that personality types affect social network positions and developmental patterns (Burt et al., 1998; Mehra et al., 2001). Studies on WTC also demonstrate that communication styles significantly influence various communication behaviors and outcomes including new relationship building, diversity of relational linkages, leadership, and performance (McCroskey, 1987; Richmond & McCroskey, 1989; Richmond & Roach, 1992).

In sum, the aforementioned literature suggests that learners with dissimilar communication styles should act differentially in a networked learning environment, and as a result, build diverse types of social networks. For example, high WTC learners might be more apt or inclined to seek out new relationships in a CSCL setting than low WTC learners. They are more likely to explore new relational opportunities and assets such as information, skills, and knowledge accessible through collaborative learning social networks. On the contrary, faced with high communication uncertainty due to factors such as mediated technology or disposition, low WTC communicators may be more interested in investing in close social relationships in which they and their partners can be trusted, and, thus, create small but cohesive social circles (McCroskey, 1997). Hence, we predict:

Hypothesis 1a: High WTC learners will be more likely than low WTC learners to explore new social ties and links when they participate in CSCL settings.

Similarly, we hypothesize that learners with high WTC are more likely to actively build up new connections, create social networks with heterogeneous partners, and thus more actively participate in networked learning activities. As a result, those with high WTC are expected to occupy central positions in a collaborative learning social network.

Hypothesis 1b: High WTC learners are more likely than low WTC learners to occupy central positions in an emergent collaborative learning network.

### 2.3. Pre-existing friendship network

Incorporating the structuralist perspective, we also hold that emergent network social structures are not only determined by individual communication styles and volition, but also influenced by pre-existing social and structural elements of a given social system. As Emirbayer and Goodwin (1994) suggested development of any new social system is dependent upon and constrained by previous social structures, histories, and ties. That is, social networks “exhibit aspects of both *emergence*, being called into existence to accomplish some particular work, and *history*, drawing on known relationships and shared experience” (Nardi, Whittaker, & Schwarz, 2002, p. 207). Consistent with this argument, studies have shown that a pre-existing network, such as a friendship network, becomes a relational foundation, which provides a base for quick formation of multiple communication and social support networks in various social settings (Jehn & Shah, 1997). A pre-existing social network also has strong effects on the formation of computer-



mediated relationships and social networks. Evidence suggests that “electronic links primarily enhance existing interaction patterns rather than creating new ones” (Bikson, Eveland, & Gutek, 1989, p. 102). Child and Loveridge (1990) found that CMC was designed precisely to support ongoing hierarchical relations, while more recently, Wellman, Hass, Witte, and Hampton (2001) observed that people’s interaction online supported pre-existing social capital by supplementing face-to-face contacts.

In a typical CSCL setting, students often recruit existing friends and colleagues when they participate in a new learning program. As a result, some take central/peripheral positions from the beginning, and this initial social structure may significantly enable or constrain how distributed learners create and benefit from emerging social networks (Cho, 2002). Accounting for this structural force of a pre-existing social network, we predict:

H2: Learners’ initial positions in a pre-existing friendship network will significantly affect the ways in which distributed learners develop new social ties and move into different social groups in an emerging collaborative learning social network.

#### 2.4. Social network and learning performance

Finally, in order to investigate the impact of emergent social network qualities on learning outcomes, the current study examined the relationship between social network positions and learning performance. According to the social network perspective, some individuals may outperform their peers because they occupy structurally advantageous positions than others in social networks. In general, social network studies conducted in organizational settings demonstrate that network positions have significant impacts on individual and organizational outcomes because the structure of social interactions enhances or constrains access to valued resources such as task advice, strategic information, social support, and so forth (Brass, 1984; Ibarra, 1993). Centrality, the degree to which an actor is connected to others in a given social network, is reported to confer various instrumental benefits such as promotions (Burt, 1992), power (Brass, 1984), and innovation (Ibarra, 1993). Centrality also leads to a broad base of psychosocial and social resources, providing the assistance and social support necessary for high performance (Ibarra, 1993).

In searching for the optimal network position most strategically advantageous to individuals (e.g., “being in the right place (Brass, 1984)”), SNA has examined two different network positions, degree centrality and brokerage positions. Degree centrality refers to the extent to which an individual actor has numerous links to other members in a given social network. It is assumed that actors with high degree centrality must be the most active, prestigious, powerful, and more visible than marginal actors, due to the many ties and connections they have to other actors in the network or graph (Freeman, 1979). High degree centrality is positively associated with individual performance, because it maximizes an actor’s access to any number of resources that may be important to success in many venues (Brass, 1981; Sparrowe, Liden, & Kraimer, 2001). Degree centrality also implies control over the resource acquisition of others, because central individuals can choose from a greater number of alternative individuals when exchanging beneficial resources (Brass, 1984; Ibarra, 1993).

A number of social network studies, however, have suggested that brokerage positions (e.g., structural holes) provide distinctive advantages, as compared to degree centrality. Social actors who connect disconnected others tend to gain both information and control benefits, and the

actors occupying these brokerage positions have more control over diverse resources located in multiple sub-groups. Findings from small-group experiments showed that people with exclusive relations to otherwise disconnected contacts tended to gain greater resources (Cook & Emerson, 1978) while individuals with ties across social divides gain non-redundant information conferring opportunities and again, greater resources (Burt, 1992).

Relatively fewer studies have examined the effects of social networks on individual performance or outcomes in educational settings. Haythornthwaite (2002) noted that network relationships among distributed learners led to the exchange of more kinds of information and increased sense of belongingness. More direct evidence of the impact of social networks on learning performance was reported in a few studies conducted in traditional educational settings. For instance, network centrality among MBA students' teams significantly influenced learners' performance, team outcomes, and satisfaction with the learning program (Baldwin, Bedell, & Johnson, 1997). Among different types of social networks such as friendship, communication, and adversarial networks, communication networks had most direct influence on MBA students' final grades (Baldwin et al., 1997; Sparrowe et al., 2001). It was assumed that, similar to organizational settings, learners occupying central positions in collaborative learning social networks have superior access to information, knowledge, and social support.

The current study sets out to test whether the significant network effects manifested in previous studies (Baldwin et al., 1997; Sparrowe et al., 2001) can be externally validated to a distributed learning environment where social networks formed by participants are significantly different from those of traditional classroom members.<sup>5</sup> CSCL is an interesting study site to examine the effects of social networks in many venues. On one hand, social networks may have a more significant impact on learning performance in a CSCL setting, since learning activities in such a collaborative environment are predominantly based on communication, social interactions, and coordination among distributed learners. Hence, the degree to which an individual invests in new social and intellectual capitals (Nahapiet & Ghoshal, 1998) or explores relational assets (Leenders & Gabbay, 1999) would have significant impact on any individual's performance. On the other hand, social networks may have less instrumental impact on learning outcomes due to the lack of information channel capacity and cues-filtered out nature of CMC channels (Culnan & Markus, 1987; Trevino, Lengel, & Daft, 1987). Social networks and social capitals mediated by CMC channels tend to be shallow, minimal, and less socially rich (Trevino et al., 1987), and therefore would be less influential or instrumental on learning performance (see Walther (1996) for a counter argument). In order to investigate the impacts of social networks on learning performance in the context of CSCL, hence, we explore the following research questions.

Research Question 1-1: To what extent do social networks influence learners' performance in a distributed CSCL community?

While previous studies examined advantages and disadvantages of different network positions and roles in organizational settings, there has been no research to date that has explicitly evaluated how various network positions are associated with performance in the context of distributed learning, where network forms, the nature of social interactions, and other contextual and

<sup>5</sup> Yang and Tang (2003) confirmed the significant relationship between social networks and learner performance in the context of online forum discussion. However, participants in this study were from the same classroom and interactions are confined to a traditional in-classroom boundary.



communicative settings significantly differ from those in business organizations. Hence, we further investigate:

Research Question 1-2: Which type of network position will be the most instrumental for participants in a distributed learning environment?

### 3. Methods

#### 3.1. Study site and sample

The data for this study were collected from a multi-year CSCL/CSCW research project. The goal of the project was to develop the capability for individuals at distributed geographic locations to interact effectively on development of future aerospace systems. As a part of this larger research project, a distributed CSCL course was co-hosted by two engineering schools at two large eastern universities in the US. Due to requirement for intense collaboration and coordination among remote learners, the class size was set to a small group setting. Sampling of students for this study was conducted on a first come first serve basis during each institution's course enrollment process. Altogether, thirty one senior and graduate-level engineering students enrolled in a year-long design course (14 from University A and 17 from University B). Among the students, 23 were male (Univ. A = 9, Univ. B = 14) and 8 were female (Univ. A = 4, Univ. B = 4).

One key feature of this CSCL course was that the distributed virtual teams, consisting of students from two remote locations, had to work closely together in order to design a future aerospace system. The group task focused on the design of the structural sub-system for the next-generation space shuttle, a reusable launch vehicle (RLV), and because of the RLV's complexity, the group task was highly interdependent, cooperative, and multidisciplinary in nature. The teams worked on specific design issues regarding materials and structure, as well as on thermal control and thermal protection. To create effective designs, distributed learners had to be aware of the overall system engineering. However, at the same time, they needed to cooperate and collaborate with others, since each group member had to specialize in one specific area. To create a full multidisciplinary experience, NASA engineers interacted with the class to address such disciplines as propulsion systems, hydraulics, aerodynamics, human factors, and cost analysis. In the first semester, the students considered alternative designs for elements and systems of the RLV. In the second semester, a detailed design was produced, complete with virtual manufacturing, construction and testing. The course ended with a presentation to NASA.

The course emphasized community-level collaboration, cooperation, and socialization among distant learners so that skills, ideas, knowledge, and social support could be exchanged across the boundaries of design teams, classes, and universities. As a means of supporting these collaborative learning activities, a Web-based collaboration and communication system, called advanced interactive design environment (AIDE), was developed. The AIDE is a Web-based portal providing a suite of integrated tools including simulation, application sharing, communication, networking, information retrieval, custom information storage, as well as instructor-provided material. The communication tools include real-time audio/video (AV) conferencing, chat and instant messaging (IM), email, and discussion boards. Distributed team members could collaborate on the design project by simultaneously running engineering simulations, sharing

applications, exchanging design ideas using digital white boards, etc. (see Fig. 2 for a screenshot of the AIDE collaboration system). Additionally, learners could retrieve information and documents by using a natural language search engine. The AIDE also provided public and social knowledge space through which distributed students freely exchanged ideas and suggestions via email, IM, and online discussion boards. Besides information exchange relevant to the group task, students were strongly encouraged to have social interactions with other students to build a sense of belongingness within the class. To enhance a sense of community membership, students also participated in two team building exercise events held in one of the universities in the beginning of the course year. Team level achievements were also frequently posted on the shared web space so that distributed learners could exchange their comments, experiences, ideas, and suggestions for improvements across the boundaries of design groups and universities.

### 3.2. Data collection

Two separate surveys were administered in the beginning and at the end of the study year, respectively. The first survey was administered in the second week of the first semester to measure any pre-existing networks. Students were asked to look carefully at the class roster and indicate up to five persons whom they most frequently communicated with, and were asked how often they communicated with them during a typical month. Considering these networks were measured before students participated in the group aspects of the design project, and that upper class and graduate students belonged to the same departments or schools for years, it is assumed that the reported relationships were pre-existing friendships rather than any other type of instrumental relation. The first social network survey also contained scale items for communication styles (see below for a description for this measure). In subsequent data collection (at the end of the second

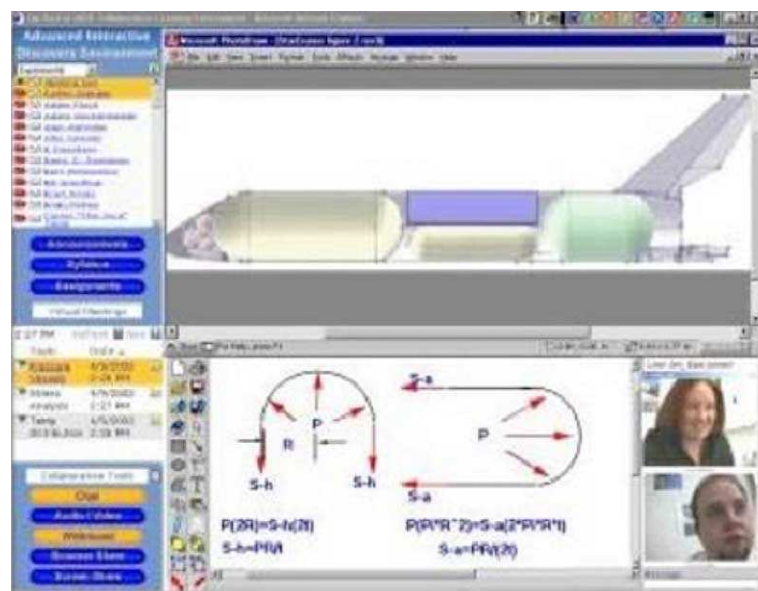


Fig. 2. Screenshot of AIDE.

semester), students were asked to report names of people they talked to for information exchange. Information exchange refers to communication about class, coursework, or design projects. Multi-item self-report Likert type scales ranging from 1 to 7 were used to measure all variables.

### 3.3. Measures

#### 3.3.1. Communication styles

To measure individuals' communication styles (WTC), a self-perception of communication competence (SPCC) scale was used (McCroskey & McCroskey, 1988). This measure was selected because it is based on a relatively simple structure, but covers quite comprehensive communication situations. More specifically, a combination of 12 scale items produced different subscales measuring an individual's comfortableness with speaking to acquaintances (Chronbach's  $\alpha = 0.65$ ) or strangers ( $\alpha = 0.74$ ) in different contexts. The scale also produced one situation-specific subscale measuring an individual's willingness to communicate with different types of people in a large group meeting ( $\alpha = 0.72$ ).

#### 3.3.2. Pre-existing friendship network positions

Individuals' initial network positions in a pre-existing friendship network were measured by two network centrality indices, closeness and betweenness. The two indices were selected according to the assumption that closeness and betweenness were to have the greatest influence on how network distribution creates newer social and collaborative learning networks.<sup>6</sup> *Closeness* centrality measures the degree to which an individual is close to all other members in a given network. Closeness measures can be conceptualized as the "ease of access to others" (Burkhardt & Brass, 1990, p. 113). An individual who is maximally close would have direct, unmediated relationships with all other members of the network. *Betweenness* centrality measures the frequency with which an actor falls between other pairs of actors on the shortest or geodesic paths connecting them (Freeman, 1979, p. 221). The higher the betweenness score of an actor, the greater the extent to which that actor serves as a structural conduit, connecting others in the network.

#### 3.3.3. Collaborative learning social network

Hypothesis 1 and 2 predict that CS (H1) and pre-existing network positions (H2) will significantly influence the formation of a collaborative social network. The development of collaborative social networks was captured by two measures, *change propensity* and *degree centrality*. Change propensity measures the extent to which an individual explored new social links and circles as the person participated in a CSCL community. Conceptually, change propensity observes how actively an individual has acquired new relational resources and assets in his or her own social circle (i.e., ego network). In other words, it indicates the degree to which an individual renewed his/her social and intellectual capital as the person participates in a new learning environment. Operationally, it is computed by using the following formula:

<sup>6</sup> Originally, we intended to use four centrality indices such as degree centrality, closeness, betweenness, and structural holes. However, multicollinearity diagnostic test showed that degree centrality and structural holes had strong correlations with closeness and betweenness, respectively. In order to avoid the multicollinearity problem and because of the parsimony rule, we used closeness and betweenness for H2. As closeness and betweenness are conceptually similar to degree centrality and structural holes, respectively, we assume that the selected measures can be comprehensive enough to cover various network qualities.

$$\text{Change propensity} = \frac{\text{The number of new network ties added in one's social network(Phase II)}}{\text{The total number of network ties in one's pre-existing social network(Phase I)}}$$

For instance, if person “x” initially reported a, **b**, **c**, d, e as her/his interaction partners in phase I (pre-existing network) and then reported **b**, **c**, f, g, t in phase II, then the change propensity for this particular individual in phase II is 0.6 (3/5).

Degree centrality refers to the number of ties (connections) that an actor holds in a given social network. In our study, it conceptualizes the degree to which an individual learner is deeply embedded in an emergent collaborative learning social network ([Baldwin et al., 1997](#)).

For RQ 1-1 and 1-2, we examined the degree to which emergent social network properties influenced learning performance. Studies have shown that different network properties distinctively influence individual performance ([Brass, 1981](#); [Sparrowe et al., 2001](#)). Hence, four different centrality measures such as closeness, degree centrality, betweenness, and structural holes were used to capture various network qualities. *Structural holes* measures the degree to which an individual has exclusive exchange relations to otherwise disconnected partners and groups. Individuals with more structural holes are positioned for entrepreneurial action as they can control the flow between people on opposite sides of structural holes ([Burt, 1992](#)).

#### 3.3.4. Learning performance

Students' learning performance was measured by their final grades in the second semester of CSCL class. Students' grades were calculated through a combination of final exam score, group assignment evaluation, and peer-evaluation. The group assignment evaluation was based on the final design outcome, written reports, and the presentation to NASA. Overall, students' final grades were significantly related to CSCL activities since the group project consisted of more than half of their final grades. Also, the distance learning classes were designed to support the group project especially in the second semester. For instance, in a course lecture, students briefly reported weekly progress of their project in the beginning, and lectures and class discussion were followed. The final grades were allocated on a 1–4.3 scale ( $M = 3.28$ ,  $SD = 0.63$ ).

Of course, the measurement of student performance is certainly open to many definitions. Depending upon the content of the course or the nature of the students, learning performance can be measured by many different ways such as successful completion of a course, course withdrawals, grades, added knowledge, and skill building ([Yang & Tang, 2003](#)). However, it is not the intention of this study to measure the students' perception of learning experiences, but rather to measure their credit achievements in the CSCL course. Given that students' final grades have been used to measure learning performance in various DL and CSCL contexts ([Alavi, 1994](#); [Johnson, Aragon, Shaik, & Plama-Rivas, 2000](#); [Loomis, 2000](#); [Parker, 2001](#); [Yang & Tang, 2003](#)), we assumed that this measure would be appropriate for this study.

## 4. Results

As for Hypotheses 1 and 2, multiple regression analyses were conducted in order to examine the degree to which CS and pre-existing network positions influenced the way individuals created new social networks when they participated in a networked learning program. In the regression

Table 1

Results of regression analyses predicting an individual's propensity to change social network composition showing standardized beta

	Step I	Step II	Step III
WTC			
Communicate with acquaintances	0.323 ( $p = .06$ )	–	–
Communicate with strangers	–	0.180	–
Communicate in a group meeting	–	–	0.165
Closeness	–0.575**	–0.507*	–0.539**
Betweenness	–0.054	–0.069	–0.088
R-Square	0.450	0.376	0.374
Adjusted R-square	0.368	0.282	0.280

\*  $p < 0.05$ .

\*\*  $p < 0.01$ .

models, the three communication style measures and initial network positions (centrality) were entered as independent variables to predict each of the dependent variables, i.e., change propensity (H1a) and degree centrality (H1b).

Note that we centered both the communication style and centrality variables in order to correct for multicollinearity problems. To check on the severity of the multicollinearity among the independent variables, we examined the conditioning index and variance proportions associated with each independent variable (see Belsley, Kuh, & Welsch, 1980, for a discussion). According to Tabachnik and Fidell (1996, pp. 86–87), a conditioning index greater than 30 and at least two variance proportions greater than .50 indicate serious multicollinearity. The multicollinearity diagnostics displayed that, even after the measures were centered, the three communication styles had severe multicollinearity problems. Hence, we decided to run three separate regression analyses, by entering each communication style variable at a time to avoid serious threats to the validity of our findings. Since the two social network variables displayed no multicollinearity problem, those two variables were included in the regression model simultaneously.

Table 1 summarizes the results of multiple regression analyses for Hypothesis 1 and 2. Hypothesis 1a was partially supported. Among the three communication style variables, “willingness to communicate with acquaintances” displayed a marginally significant relationship with the change propensity ( $b = 0.323$ ,  $p < 0.06$ ). Given that this analysis was based on a very small sample size, the 0.06 level results were deemed to be noteworthy.<sup>7</sup> It indicates that those who were more willing to communicate with acquaintances more actively explored new social ties in this particular CSDL community. As a result, they significantly changed their network partners as they participated in the emergent social structure. Other measures for communication styles such as “willingness to

<sup>7</sup> Note that the sample size is reduced to 25 from 31 for this particular analysis, since we excluded six students who were identified as social isolates in a pre-existing network. Since these students had zero or one network partners in the pre-existing network, computing the dependent variable of H1, the degree to which they changed their network composition, would be less meaningful and bias the final results (denominator is zero or 1 in the formula). For all the other analyses, we kept the original 31 student sample size. To test whether the deletion of these people made any significant changes in the results, additional analyses were conducted including those people in the regression model. The results were almost identical except for small changes in coefficient values. Overall, the model fits were lowered and closeness became a less significant predictor (but still significant at 0.01 level)

Table 2  
Correlations between social network properties and learning performance

	1	2	3	4	5	6	7	8	9	10
1. Degree I (pre-existing)	–									
2. Closeness I	0.645**	–								
3. Betweenness I	0.452*	0.316	–							
4. Structural holes I	0.078	0.738**	–0.062	–						
5. Degree II (emergent)	0.281	0.312	–0.018	0.288	–					
6. Closeness II	0.167	0.279	–0.230	0.312	0.641**	–				
7. Betweenness II	–0.177	0.178	–0.277	0.494**	0.296	0.406	–			
8. Structural holes II	–0.393	0.301	–0.291	–0.089	–0.320	–0.118	–0.013	–		
9. Grades (Semester I)	0.349 ( $P = 0.059$ )	0.441*	0.112	0.112	0.257	0.301	–0.066	–0.175	–	
10. Grades (Semester II)	–0.171	–0.175	–0.015	–0.037	0.341 ( $p = 0.065$ )	0.442*	0.227	0.076	0.421**	–

\*  $p = <0.05$

\*\*  $p = <0.1$ .



communicate with strangers” or “willingness to communicate in a large group,” did not display any significant relationships with the dependent variable, i.e., change propensity. It seems that participants in this learning community considered other members in the community as acquaintances, rather than strangers.

Hypothesis 2 was also supported in that students’ initial network positions had negative effects on change propensity. As shown in the table, closeness displayed a significant relationship with *change propensity* ( $b = -0.575, p < .01$ ). The result indicates that those who were maximally close to all other members in the pre-existing network were less likely to form new ties and links in the later periods. In other words, those who were central in the pre-existing network were more likely to stay in their initial social circles, whereas peripheral actors were more likely to alter their network compositions, since they are not bound to pre-existing networks. The results suggest that an actor’s centrality in a pre-existing network generally confine people in pre-determined social circles.

Hypothesis 1b was not supported. We ran another set of the regression analyses using the same independent variables to predict degree centrality. Neither the communication style nor the network measures displayed significant associations with the dependent variable, *degree centrality*.

As for RQ 1-1 and 1-2, we examined the degree to which emergent social network properties influenced learners’ performance in a CSCL community. To answer these two questions, we tested the associations between individuals’ social network properties at the time of the second survey (Time II social network) and their final grades in the second semester. We conducted bi-variate Pearson correlation tests instead of multiple regression analysis in order to avoid the above mentioned multicollinearity problem. When we checked for multicollinearity among network measures in the time II social network, the diagnostic tests reported severe multicollinearity problems among the measures.

The results of correlation analyses are reported in Table 2. As shown, closeness centrality was significantly associated with students’ final grades in the second semester ( $r = .442, p = .014$ ). The other network variable, degree centrality, also displayed marginally significant association ( $r = .341, p = .065$ ). The results indicate that the position of individual learners in a social network significantly influenced learning performance in a CSCL community. In other words, those who occupied central positions in a given learning network were more likely to get high performance rates in a distributed learning community. Note that these results are based on correlation analysis. Therefore, the significant relationships do not indicate the causal influence of network centrality on learning performance. It is possible that, for example, high performers tended to occupy central positions from the beginning. If this is the case, network variables are the outcomes of learning performance rather than antecedents. To test the plausibility of this alternative argument, we checked students’ grades in the first semester (semester I) and tested if students’ performance in previous semester influenced their network positions in the following semester. As shown in Table 2, none of associations are significant, indicating that we can eliminate this line of alternative reasoning.

## 5. Discussion

It has been argued that in order to foster a CSCL community, it is not enough to implement new instructional technologies or collaboration systems, but an appropriate *social infrastructure*,

i.e., social networks and practices that support desired interactions between the participants (Bielaczyc, 2001) should also be put in place. By adopting a relatively new analytical tool in this field, (i.e., SNA) we empirically investigated emerging social structures and collaborative patterns, key elements of this social infrastructure in a distributed learning community, and tested the antecedents and outcomes of collaborative learning social networks.

To summarize, we found that both psychological (individual communication styles) and structural (a pre-existing friendship network) factors significantly influenced the way distributed learners created collaborative learning social networks. As predicted by H1a, we observed that individual differences in communication style resulted in structural differences in ego network composition. That is, high and low WTC individuals pursued different network strategies, with high WTC learners tending to explore new social worlds and add new relational ties, and low WTC learners tying to more small and trustful social worlds. It suggests that just as people differently manage human and finance capitals, people with different communication styles invest, manage, and utilize their social capital in a different way.

Additionally, a pre-existing friendship network significantly influenced the emergence of collaborative social networks. Students who were holding many strong social relationships in an initial pre-existing social structure were more likely to stay in their initial social circles, whereas initially peripheral actors tended to form more heterogeneous relationships and freely moved into different social circles. Leenders and Gabbay (1999) suggest that pre-existing social ties have both functional and dysfunctional impacts on network-based activities. On one hand, pre-existing social network properties can be social capital, enabling an individual to build up new relational assets by leveraging his/her own existing social ties. On the other hand, pre-existing social ties become a social liability when they restrict one's ability to renew his/her existing capital by confining the social actor to pre-determined social circles (Gargiulo & Benassi, 1999). The negative  $\beta$  coefficient reported in this study suggests that pre-existing network ties acted as a *social liability* that significantly constrained an actor's ability to explore new social contacts and resources when s/he was making a transition into a new learning environment, or a CSCL community.

As hypothesized in the original research model (see Fig. 1), we assumed that the two antecedents, communication styles and a pre-existing social network, were independent sources of influences on the development of a collaborative learning social network. However, it can be argued that the two antecedents are rather interrelated factors as communication styles may have influenced the network positions of individuals in a pre-existing network. For instance, high WTC individuals might have occupied central positions in a pre-existing network from the beginning. This alternative reasoning assumes that communication styles would have only *indirect* influence on the social network outcome through the mediation of the pre-existing social network (see Fig. 1). However, a correlation test checking the association between the two factors displayed that there was no significant relationship, which instead supports our original research model.

With regards to H1b, we failed to support our hypothesis that communication styles would influence final network positions (i.e., centrality) of individual learners. While communication styles (WTC) significantly influenced the way individuals composed their ego network (H1a), it did not affect their final network positions in a larger social system (H1b). The failure to support H1b is not surprising given that this particular result is somewhat consistent with the structuralist arguments made in SNA studies. As noted before, the SNA literature suggests that network position in a larger social structure should not be solely determined by a focal individual's personality

or volitions, but influenced by behaviors of multiple network actors and other structural forces (Wasserman & Faust, 1994). Although a social network consists of individual actors and their relationships, the resultant larger social structure is not just a simple sum of many components. In other words, while an individual can decide whom to communicate with or how to compose his or her social capital, the person cannot determine his/her own network position through conscious activity since it is often based on thousands of direct or indirect network linkages. The results suggest that future researchers need to be aware of the multi-faceted nature of the relationship between individual differences and social network formation. As noted above, CS influenced a social network outcome in the ego (individual) level analysis (change propensity) but not in the network level analysis (centrality). It suggests that level of analysis and conceptualizations of network outcomes should be important issues for future researchers focusing on the interrelationship between individual characteristics and the social network.

With regards to the effects of a social network on learning performance (RQ1-1), this study demonstrated that a social network in a CSCL community had a tangible impact on individual performance. Students who occupied central positions in the emergent collaborative learning network tended to demonstrate higher levels of learning performance. As reviewed earlier, the social network literature generally confirms that individuals often outperform their peers when they occupy more strategically advantageous positions. The remaining question is “which positions are most instrumental for distributed learners in a CSCL setting? (RQ1-2)”.

While the results do not provide an ultimate answer for this broad research question, findings of this study indicate that *degree* and *closeness* centralities than brokerage positions (*structural holes* and *betweenness*) have more significant impacts on learning performance. This particular result differs somewhat from the findings of previous SNA studies conducted in organizational settings where researchers found that brokerage positions than degree centrality had more significant impacts. It suggests that, at least in some educational settings, access to members of the community, leading to greater opportunities to gather information and psychological/social supports would be more important than control over strategic information and resources. We speculate that unlike people in business organizations, learners in our particular CSCL community seldom engaged in strategic competitions over exclusive and limited resources. Hence, in a CSCL community, network positions providing members with more (degree centrality) or quicker (closeness) access to numerous others would be more valuable than those positions providing resource control and entrepreneurial advantages (structural holes, betweenness, or power). It suggests that researchers should take account of contextual factors when examining the impact of social and structural elements on network-based learning/work activities and outcomes.

The associations between a pre-existing network and learning performance are also noteworthy (see Table 2). Centrality in a pre-existing friendship network (closeness and degree) displayed positive relationships with learning performance in the first semester, but negative (non-significant) relationships in the next semester. In the second semester, only centrality in a collaborative learning social network had significant, positive impacts on learning performance. It appears that, as the social structure in a CSCL community changes, networked learners also need to adapt to a new learning environment and invest in renewing their own social capital to perform better. As proposed by the “strength of weak ties” hypothesis (Granovetter, 1973) tight bonds among strong ties (such as friendships) tend to create closed social circles, which maybe useful at the formation of a social network. Tight bonds, however, can become exclusive, presenting an insurmountable

barrier to a new entry with new information. On the contrary, weak ties confer more benefits because unique information is often exchanged through weak ties which tend to span across heterogeneous social groups. Taken together, it suggests that investing in new social links and engaging in social interactions with remote partners should be very important for distributed learners in the context of collaborative learning, as these activities provide opportunities for building new social capital and relational assets in a CSCL community.

## 6. Conclusion, limitations, and directions for future study

In sum, the present study has some theoretical, methodological, and practical implications for researchers and practitioners in the field of CSCL. Theoretically, findings of this study render empirical support for the new notions of learning and knowledge centering around the premise that learning is indeed a social and communication outcome (Brown & Duguid, 1991; Harasim et al., 1995; Lave & Wenger, 1991; Nonaka & Konno, 1998). The study demonstrated that CS and a pre-existing social network played a significant role in shaping how distributed learners act in a networked learning environment. We also found that learners' performance is an actual outcome of emergent collaborative learning social networks. Given that there is a dearth of empirical research to support many theoretical claims of CSCL (Woodruff, 2002), this study is valuable in demonstrating the possible relationship between communication styles and social network variables to learning outcomes in a CSCL learning environment.

The study also proposes that adding personality theory (CS) to structural analysis (SNA) should help forge a useful approach to understanding individual behavior in the context of social structure. Taken together, a combination of these somewhat opposing disciplines contributes to an enhanced picture of how distributed learners with different characteristics build their social and intellectual capitals in a computer-mediated social system. As Mehra and his colleagues suggested (2001), future research may benefit from the further integration of modern social network analysis and the rich traditions of psychology, as opposed to the acceptance of an inevitable duality between those interested in the psychological determinants of individual behavior and those interested in how network structures affect social processes (Emirbayer & Goodwin, 1994).

In a more practical sense, the current study suggests that we should focus both on individual characteristics as well as social/structural elements when designing CSCL activities and environments. Although many have highlighted the importance of "social infrastructures" in CSCL (Bielaczyc, 2001), we often assume that technology will automatically connect remote learners and promote borderless exchange of information, knowledge, and skills among distributed individuals and teams. In order to support seamless participation among network learners, however, one should fully take into account such social and individual factors as a pre-existing network or communication styles in the design of a CSCL community. For instance, educators may administer a personality survey and match low WTC individuals with high WTC as peer or team members in order to facilitate more seamless collaboration among all members in a CSCL community. Similarly, the study showed that network centrality significantly influenced students' final learning performance, indicating that some students were structurally advantaged or disadvantaged due to their network positions. Social network analysis can be conducted during the semester to

identify central or peripheral members, and this information might be helpful to redesigning social infrastructures in a learning community.

Finally, in a methodological sense, this study suggests that social network analysis can be a valuable analytical tool to examine complex social processes and outcomes in a CSCL community. As illustrated in this study, social network analysis was effective in delineating and understanding emerging social structures and collaborative patterns. SNA also enabled us to investigate the degree to which these social and structural elements affected learning performance in a networked learning environment. Future research may adopt this relatively new analytical tool in the field of CSCL, and to further test out the complex interplays between social structures, learner behaviors, and collaborative learning activities.

Before we conclude our study, we would like to mention some important limitations of the study, together with directions for future research. First, the CSCL community examined in this study consisted of relatively small, homogeneous learning groups. Studying social phenomena using a small sample size is not unusual in social network research due to the extreme difficulties gathering such rich and complex information (Wasserman & Faust, 1994). Yet, the small sample size restricts the researcher from generalizing findings of the current study to broader social settings, given the complexity of the model to be tested. Similarly, the research site was situated within a special educational context; and all subjects were college engineering students. Caution is advised in attempts to generalize findings to other social settings where social dynamics and structures may be significantly different. Hence, we emphasize that findings and implications of this study are only tentative and preliminary in nature until they are to be further tested and validated by future research employing larger samples in different contexts.

Second, this research concentrated on the potential benefits of social networks but omitted the negative impacts of social networks in CSCL settings. While a large body of social network or social capital research has focused on the benefits of social capital, this position is increasingly viewed as overly one-sided (Leenders & Gabbay, 1999). Social structures change over time, as do their effects on individuals. Hence, relationships and social capital beneficial to the achievement of goals in the formation of a social network may thwart goal attainment as the network evolves and ages. Considering that researchers have only begun to characterize the conditions that determine the relative importance of positive and negative effects of social networks (Adler & Kwon, 2002), we suggest that future researchers would benefit from taking a longitudinal approach to the effects of time on social networks. In the rapidly changing social environment of a CSCL community, new forms of learning and the establishment of working ties can prove to be ephemeral, and the continued study of these technological ecologies over time may lead to a greater understanding about the role and effects of social networks in computer-mediated environments.

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