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Patterns of Interaction in Computer-Supported Learning: A Social Network Analysis

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Abstract: The purpose of the study was to analyze patterns of elementary school students' peer interaction in a computer-supported classroom. The problem addressed in the study was whether students representing different level of school achievement and gender would productively participate in progressive discourse. Technological infrastructure of the study was provided by the Computer-Supported Collaborative Learning Environments (CSILE) The study applied social network analysis to investigate written comments logged by 28 grade 5/6 students to CSILE's database. The study indicated that although the density of interactions within the CSILE class was rather high, there were large individual differences in regard to participation in CSILE-mediated discourse. Further, the analysis revealed that average- and high-achieving female students dominated discourse interaction within the CSILE class, and carried the main responsibility for all students' collaborative building of knowledge. An important characteristic of CSILE students' culture of interaction was that female and male students interacted mainly within their respective gender groups. Within the groups a significant amount of communication took place between students representing different achievement levels. It is concluded that social network analysis provided new information about patterns and structures of CSILE students' interaction culture that would have been very difficult to obtain by any other means.

Keywords: computer-mediated communication, discourse, learning environments, social cognition.

Introduction

The purpose of the study is to analyze patterns of interaction between elementary school students collaborating within a computer-supported classroom. The study focused on analyzing whether students representing different levels of school achievement and both genders would engage in progressive discourse interaction aimed at advancing their knowledge and explanations. The technical infrastructure for the study was provided by the Computer-supported Intentional Learning Environments, CSILE (Scardamalia & Bereiter, 1993). CSILE is a networked learning environment for fostering higher-level processes of inquiry in elementary education. The system provides a shared space for producing, searching, classifying, and linking knowledge. The system facilitates sharing of cognitive achievements by providing each student an access to all textnotes, comments and charts produced by fellow students. CSILE is designed to foster collaborative learning through its advanced facilities for searching out and commenting on fellow students' productions.

Hakkarainen's (1998a; 1998b) study indicated that CSILE students engaged in a very intensive explanation-oriented peer interaction. Progressive discourse characteristics of CSILE students emerged gradually through experimenting with and testing different types of pedagogical practices. The study indicated that with teacher's guidance the students were able to participate in peer interaction focused on providing and requesting explanations that facilitate advancement of their explanations. It was concluded that written communication between the students appeared to support all groups of students and to be an important resource for conceptual advancement. The 1998 studies used qualitative content analysis, examining frequencies of different types of CSILE students' comments as well as proportions of certain types of comments (e.g., explanation-related comments). However, the methods applied did not allow a detailed examination of relations among the CSILE students. Even if certain differences between female and male students were mentioned, the students' culture of inquiry was regarded as more or less homogeneous across students. Many other CSILE studies, insofar as they did not investigate heterogeneity, were implicitly or explicitly based on the same sort of assumption (e.g., Scardamalia & Bereiter, 1993; 1994).

Sfard (1998) distinguished between two metaphors of learning, i.e., the *knowledge acquisition metaphor* and *participation metaphor*. The former represents a traditional view according to which learning is mainly a process of acquiring desired pieces of knowledge. In this view, the human mind is a container that is filled with knowledge structures and the learner is an owner of the knowledge constructed. The latter, in contrast, examines learning as a process of participating in various cultural practices and shared learning activities, a process that structures and shapes cognitive activity in many ways. Accordingly, learning is seen as a process of becoming a member of community and acquiring the skills to communicate and act according to its socially negotiated norms (Lave & Wenger, 1991). The participation metaphor appears to provide a very valuable insight into the role of social community in the processes of learning and knowledge building. It appears that traditional methods focusing on examining characteristics of an individual student more or less represent the acquisition metaphor whereas completely new methods are needed in order to assess the role of participatory processes in learning.

The present study focused on uncovering the patterns of CSILE students' participation by applying methods of social network analysis that provide sophisticated statistical tools for examining relational data (Wasserman & Faust, 1995; Scott, 1991). Standard statistical methods, in contrast, provide information about attributes of individual actors rather than relationships among actors. Our goal was to examine relations among students commenting on each other's production within CSILE's database, to describe patterns of relationships among students, and to analyze the structure of these patterns. The questions addressed were a) how intensively do students participate CSILE mediated discourse interaction; b) what is the density in which students representing both genders and different school-achievement levels participated in peer interaction; c) how centralized is the students' interaction, i.e., is the discourse dominated just by a few students.

Method

The study was based on an analysis of CSILE students' written productions, posted to CSILE's database. The study material (raw data) represented productions of 28 grade 5/6 students over an academic year at an inner-city public school in Toronto, Canada. The data arose naturally while the students carried out their study projects, working with CSILE; students were not subject to any special intervention connected with the present study. Participation in CSILE-mediated peer interaction was analyzed in relation to their levels of school achievement and gender. The students' school achievement levels were assessed by the Canadian Test of Basic Skills (the CTBS). Due to the nonexperimental (authentic) context of carrying out the CSILE experiment, the students had been previously selected for the class as a part of normal school administration. Although assigning the students to the class was reported by the school to be random, the gender distribution of the students in the classroom was outside of what might be expected with sampling randomized by gender: two-thirds of the students (n=19) were females and one-third (9) males.

The study involved qualitatively analyzing discourse interactions among students. The analysis concerned computer entries, "comments," that were produced in the context of three physics (Force, Cosmology, and Electricity) and one biology science study project (Human Biology). CSILE students' postings to the CSILE database were analyzed through qualitative content analysis (see, for example, Chi, 1997). In order to make a reliable qualitative classification of the material possible, CSILE students' comments were first partitioned into ideas (regarding segmentation of data for content analysis, see Chi, 1997). The reliability of partitioning was assessed by asking two independent coders to segment 200 notes into ideas. The Pearson correlation between number of ideas identified by the two coders was .94. Ideas rather than notes were used as a unit of analysis, in order to equalize the weight of short and long comments in the students' interaction. A comment would have been a natural recording unit of content analysis. However, some students presented many ideas (e.g., provided several pieces of scientific explanation) in a single comment although others presented their ideas in many different comments.

Further, CSILE students discourse interaction was analyzed by applying social network analysis (Wasserman & Faust, 1995; Scott, 1991). Characteristics of CSILE students' social network was analyzed by examining the intensity of direct interaction among members of a learning community (density), the extent of each member's participation (centrality), and pattern of interaction in the community as a whole (centralization). The data consisted of the links between CSILE students' communicative ideas: who interacted with whom by constructing CSILE comments. The information was examined as a weighted and directed graph representing the structure of

communication, in which the teacher and the pupils were viewed as nodes and the comments as vertices. We analyzed the graph by social network analysis and multidimensional scaling (MDS). All analyses were performed by using the Ucinet program (Borgatti, Everett and Freeman 1996a).

Results

The CSILE students, taken together, produced 493 written communicative ideas. On average, each student produced 17.6 (SD = 10.7) comments. A density test is a simple way to measure characteristics of a network: the more actors that have connections with one another, the denser will be the network. The density of a (binary) network is the number of observed ties divided by the number of all possible ties (Borgatti, Everett & Freeman 1996b, p. 78; Scott 1991, p. 74). For a binary matrix, the measure varies between 0 and 1 (If the value is 0, then the network is empty. If the value is 1, it indicates that everyone is directly interacting with everyone else).

The analysis indicated that CSILE students' network of interaction was rather dense; the density was 41% for symmetrized data (direction of commenting ignored). In the case of the asymmetric graph based both on sent and received comments, the measure was 28% of the possible ties. The data set was dichotomized in these analyses (cut off point = 0).

Further, we examined how much interaction there was between students representing different ability levels and genders. Therefore, we partitioned the network into blocks the density of which was examined separately on the basis of gender (male; female) and ability level (below average; average; above average) of the students (see Table 1). In addition, the teacher formed one block. In assessing the results, it should be taken into consideration that the densities of blocks with varying sizes are not directly comparable. The limit to the total number of ties that can in reality be maintained by an individual means that larger graphs will have lower densities than smaller graphs (Scott 1991, p. 77).

The analysis indicated that male students' communication took place mostly between average and above-average males (0.53) rather than spread evenly among all ability levels in these male groups. Further, the density of interaction between male and female students appeared to be very low; male students sent only a few comments to female students (0.27 is the highest density). However, the density of comments sent by average-achieving female students to average-achieving male students was somewhat higher (0.40). It is particularly noticeable that above-average males hardly interacted at all with above-average females.

Table 1. Density of interaction across gender and ability level of CSILE students

	n	**Below-average males**	**Average males**	**Above-average males**	**Below-average females**	**Average females**	**Above-average females**	**Teacher**
Below-average males	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Average males	3	0.00	0.17	**0.53**	0,08	**0.27**	0.03	0.00
Above-average males	5	0.00	**0.53**	0.20	0.10	0.12	0.12	0.00
Below-average females	4	0.00	0.17	0.10	**0.42**	0.35	0.32	0.00
Average females	5	0.00	**0.40**	0.28	**0.50**	**0.50**	0.42	0.20
Above-average females	10	0.20	0.13	0.14	0.28	**0.46**	**0.50**	0.10
Teacher	1	0.00	0.00	0.20	**0.50**	**0.40**	**0.60**	0.00

Further, Table 1 indicates that the density of interaction within and among different groups of female students was at a very high overall level. Taking the number of high-achieving females into consideration, the density of their mutual interaction (0.50) was at a remarkably high level. Moreover, there was also rather intensive interaction between the high-achieving females and average and below-average achieving females. Finally, it can be seen that the (male) teacher, who sent 32 messages and received 3, interacted almost exclusively with the female students, commenting on their process of inquiry.

We also examined the extent to which a whole graph representing CSILE students' interaction had a centralized structure (Scott 1991, pp. 92-93). Centralization describes how tightly interaction within a network is organized around particular focal points. A centrality value is calculated for each student in order to find the most active and visible actors in the community, and it was assessed using Freeman's degree (i.e., number of sent and received comments, see Table 2). The results of the analysis indicated that the CSILE students' interaction was not very centralized (24% and 28% in the case of sent and received comments, respectively); CSILE students' communicative efforts were distributed among a relatively large number of students who actively engaged in peer interaction.

If we think of CSILE students' communication as an information flow consisting of the individual comments, Freeman's 'betweenness' value for a given student shows how often that student is found in the shortest path between two other students. Thus, it indicates the student's position in regulating information flow within the community (Borgatti, Everett & Freeman 1996b, pp. 82-87). Within a social network, interactions between two nonadjacent actors (i.e., actors who are not directly interacting) depend on the other actors who lie on the paths between the two. An actor has a high betweenness value if he or she lies between other actors within the network who are not directly connected to each other, given that the shortest distance between two actors in the network (the geodesic) is used to calculate the betweenness. To have a large "betweenness" centrality, the actor must be between many of the other actors via their geodesics (Wasserman & Faust 1994, pp. 188-192.)

Table 2 presents means and standard deviations for centrality of each student group's participation. The table reveals, however, that there were large between-student differences in the intensity of engagement in CSILE-mediated peer interaction. An examination of the table indicates that the most active students could be found among the average-and high-achieving females students in the cases of both sent or received comments. These groups of students produced approximately twice as many comments as did the male students. We also can see that female students had more partners (M=13) than male students (M=8). The fact that the average and high achieving female students had very high betweenness values (36 and 31, respectively) indicates that they had a significant role in the student's knowledge-building inquiry mediating flow of information between the other students.

Table 2. The centralization of participation across gender and ability level of CSILE students

Group		**Sent comments**		**Received comments**		**Partners of interaction**		**Measure of betweenness**	
	n	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Male students									
Below average	1	0.0	(-)	3.0	(-)	2	(-)	0.0	(-)
Average	3	10.7	(4.0)	14.7	(12.2)	8.7	(2.1)	13.9	(9.1)
Above Average	5	7.4	(5.4)	8.4	(3.0)	8.8	(2.8)	13.2	(9.2)
Female students									
Below average	4	12.8	(4.6)	16.3	(2.9)	11.3	(0.10)	12.9	(3.5)
Average	5	24.2	(10.9)	25,4	(13.8)	15.0	(2.0)	36.0	(16.7)
Above average	10	25.2	(7.9)	24.1	(7.3)	12.9	(3.8)	30.6	(22.9)
TOTAL		17.6	(10.7)	18.6	(10.5)	11.5	(4.0)	23.0	(18.7)

Further, MDS analysis was performed in order to examine whether CSILE students' discourse interaction consisted of distinguishable subcultures of interaction. MDS examines relational data in terms of space and distance (Scott 1991, pp. 151-156). The intensity of interaction was used as a measurement of closeness: the more messages the students sent or received from certain students, the closer they are situated in the MDS map (see Figure 1). The stress value, a measure of the quality of the MDS map, was at a satisfactory level (0.153). The analysis is calculated with a symmetric matrix in which the received and sent ideas are summed up.

The figure indicates that female students' pattern of participation differed considerably from that of male students. The female students formed a relatively close group that was separated from male students. A group of high-achieving female students appeared to be very close to each other indicating that their pattern of interactions closely resembled each other. In the center of the female group were the students with highest centrality and betweenness values. The teacher is located near the most active girls. Only one of the students, a male who did not produce any comments, was isolated from the rest of the students.

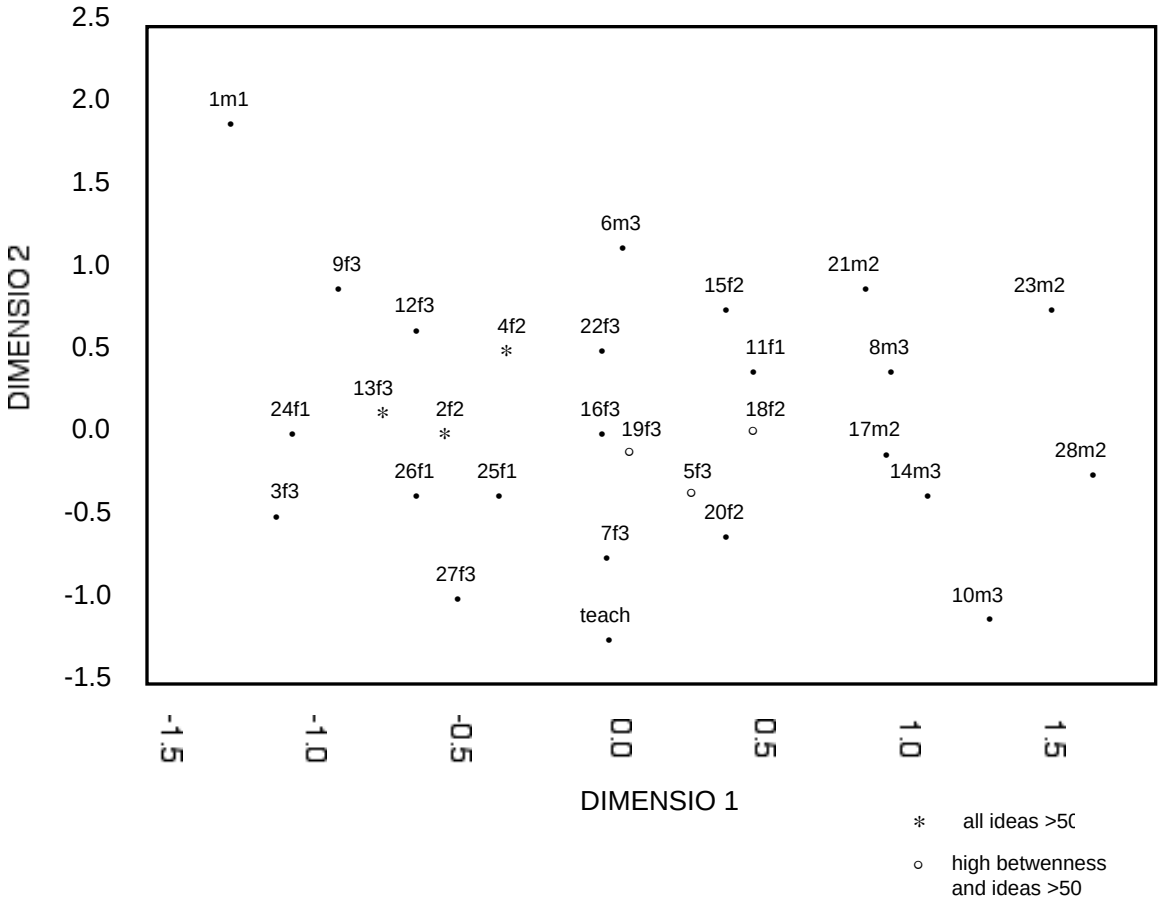

Figure 1. Female and male students' pattern of participation (based on multi-dimensional scaling) (the id number; m= males, f= females; 1=below average, 2=average, 3=above average)

The analysis indicated that 4f2, 13f3, and 2f2 were participating in very intensive interaction; they had a very high degree of symmetrized interaction (i.e., a large number of sent and received comments). They were, however, mostly interacting with other members of their small groups as well as with other female students. However, 19f3, 18f2, and 5f3 were not only engaging in very intensive dialogue with their respective group members and fellow female students but also with male students by providing and requesting explanations. Thus, they broke the boundaries of their own networks and became "starts" of the CSILE students' overall social network.

Discussion

Learning is not only an individual knowledge-acquisition process but also a process of participating in cultural practices and communities (Sfard 1998). The methods of social network analysis appeared to supply useful tools for assessing sociocognitive structures of participation in computer-supported learning rather than focusing only an individual student's activities. It provided a new kind of relational information of CSILE students' participation; i.e., patterned sets of connections that linked the students to each other. The method could also be applied to analyze a network environment's log files, and, thereby, to take a closer look at relations between students' ideas (see Nurmela, Lehtinen & Palonen, 1999). Studying the relations among participants of networked

learning, helps us to better understand and explain collaborative processes that affect the individual students: the learning cultures are formed through the accumulation of relations and influences among participants (Frank 1998).

The results indicated that the density of CSILE-mediated interaction was rather high, and practically all groups of students participated in the discourse. Yet in the interaction there were considerable individual differences as well as differences relate to achievement level. Average and high-achieving female students' communication dominated the CSILE students' culture of interaction. The male students did not engage equally actively in CSILE-mediated peer interaction. The male and female students appeared, further, to prefer communication within their respective gender groups; indeed, the MDS analysis indicated that male and female students formed two relatively distinct subcultures of inquiry.

The males students' lower level of engagement might simply reflect the skewed gender distribution in the classroom, and our evidence from a single classroom cannot rule this out; yet it is our hypothesis that a main variable accounting for engagement is the male students distinctive history of socialization in knowledge building. Male students are generally more interested in using computers than female students (see Scott, Cole & Engel, 1992) and, frequently, dominate computer-supported learning (e.g., Hakkarainen, Järvelä, Lipponen, Lonka, & Lehtinen, 1998). Nonetheless, within CSILE, where students were to use a computer network for knowledge building, the male students had a weaker showing; they did not appear to be willing to share their intuitive physical or biological conceptions as readily as did the female students. Because males generally preferred to post authoritative statements of scientific knowledge to the database, their postings did not appear to provide as fruitful a starting point for lively discussion as female students' postings that often represented their own intuitive theories and conceptions. Thus the females' engagement in this kind of intensive interaction appeared to help them make considerable conceptual advancement in their inquiry (Hakkarainen, 1998a; 1998b).

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