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Effective participation and discourse through a computer network: Investigating elementary students' computer-supported interaction

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Abstract

In this study we analyzed and described how students and teacher of one Finnish elementary class participated in and communicated through CSILE (Computer Supported Intentional Learning Environment) during the years 1997-1998. To this end, we examined the density of the interaction within class, students' participation rates, students' position in the CSILE mediated network of interaction, and the quality of their discourse. The data consisted of CSILE log files and students' written productions from the CSILE database. Social network analysis and qualitative content analysis were used to analyze the data. The findings showed that the density of interaction among participants was rather high, and all the students used CSILE to some extent. There were, however, substantial differences in the students' participation rates. The results also indicated that one student occupied a central position, and two students an isolated position in the CSILE mediated interaction. The study further revealed that the CSILE mediated discussion was composed of number of short discussion threads. The culture of CSILE mediated discourse and collaboration can be defined as follows; on topic, neutral, and providing information to others comments or questions.

Introduction

The implicit promise of computer supported collaborative learning (CSCL) has been that it will considerably change the instructional practices at school. CSCL environments, further, are anticipated to offer a medium for classroom discussions that promotes high-quality interactions among class members, leading to better learning results, both at the individual and collective level. These settings are not only expected to increase students' participation activity in classrooms but also to democratize the participation of students with different competencies and learning orientations [for a review of CSCL see, 1, 2].

This trust in CSCL is grounded, at least partly, in a body of research on collaboration. Participation in collaborative activities, with or without computers, can be considered important from several points of view. First, the more traditional story: a group can be a resource for individual learning, and offer possibilities for acquisition and internalization of knowledge. Because of engagement in collaborative activities, an individual can master something she or he could not do before the collaboration [3, 4]. People practice some new competencies and gain knowledge as a result of participation in collaborative learning. Second, the collective can be regarded as a cognitive unit that has properties different from the sum of its participants' knowledge and skills. The advocates of distributed cognition[3, 5, 6] have challenged the notion that cognition resides only "in the head" of an individual. They see cognition distributed over both individuals and their environments; knowledge and learning are "located" in these relations, and networks of distributed activities of participation. Third, the those with a situated view of cognition [7, 8] and especially the proponents of communities of practice [9], argue that to learn is to become a participant in a community, and that knowledge is an aspect of practice, discourse, and activity. All three socio-cultural approaches presented have the same important message; active participation in collaborative learning, with or without technology, is central part of one's learning and social relations.

Participation and interaction in CSCL environments

Several recent empirical studies [10-21] have demonstrated that active and broad participation and high quality interactions in CSCL environments are not automatic results. In many cases the endeavor of using CSCL has run into barriers, such as low-level participation, and unsustained and divergent discussions.

The low participation levels appear to have an impact on the continuity and quality of discourse conducted in electronic forums. The discontinuous nature of discourse in CSCL environments is reported in several studies [12, 13, 15]. The discussion threads in CSCL environments appear to be quite short--most of the threads contain only few exchanges. If the focus of discussion is simply on question and answer, as the length of the threads in online environments appears to indicate, apparently there is little hope for high-quality interactions, multiple perspectives, development of reciprocal understanding, or advancement of collective knowledge. Previous studies [17, 22, 23] have also shown that much needs to be improved in the quality of discourse in CSCL environments. The discourse patterns in these environments range from social talk (greetings, blame, keeping up social relations) to factual question-answer exchange to problem-centered and understanding-oriented discourse. Mainly, the discussions in CSCL environments tend to be shallow, evidencing divergence of ideas and building little genuine understanding [23]. In sum, these results appear to indicate that there is often a lack of sustained and on-topic discussion in CSCL environments, and this fragmented type of discussion cannot be considered very effective for learning.

However, the previous research on participation has several shortages: It is focused mainly on individual participation rates, and does not present any solid method for analysing participation on collective level. The previous research does not link together quantitative aspects (participation rates) and qualitative aspects (nature of discourse) of participation. In addition, studies concerning participation are not conducted intensively on elementary level. Further, most recent studies on CSCL concentrate mainly on students' learning processes, whereas the teacher's role has not been extensively analyzed. Moreover, there exist no well defined criteria for participation and high-quality discourse in CSCL environments.

In the following paragraphs we will propose four criterias for effective and high quality participation in CSCL environments leaning on Guzdial and Turn's ideas [13]. We will continue by reporting our research efforts aiming at filling the gaps of the previous research concerning participation and CSCL.

Towards effective participation and high quality discourse

In very recent article Guzdial and Turns [13] elaborated the idea of effective discussion in computer-mediated forums. They proposed that the best discussions in CSCL environments should be sustained, containing a number of contributions and extensive dialogues instead of short and divergent communication episodes. Such follow-through is a first step towards discourse where hypotheses are explored, perspectives are negotiated, or shared understanding is developed. Second, the discussions should have broad participation; a large number of students should engage in writing notes and making contributions in discussion forums, for one must assume that learning through discussion comes from active participation in that discussion. Third, they argue that effective discussion should be focused on class learning topics. Even if we acknowledge the importance of social discussion in activating participation in discourse, increasing motivation, and building a community, the discussions, above all, should be focused on the class learning topics. These three features constitute, what Guzdial and Turns call *sustained on-topic discussion*. They propose that sustained on-topic discussion should be the goal for discussion forums and CSCL environments. We agree with these arguments and think that these investigators are right on the mark. In our opinion, however, their definition of effective discussion needs to be expanded for it seems to leave out some important features that effective discussion should have. In the next part we expand Guzdial and Turn's arguments and propose some new features as characteristics of effective discussion through CSCL environments.

Our suggestions deal with the structure and quality of communication and are based on results of our [24, 25], and others' earlier investigations [19, 26], and are anchored in the wide framework of socio-cultural theories of learning. First, the interaction among participants should be dense [26, 27]. Participants' contributions (for instance, comments) in the CSCL environment constitute a network of interaction among participants. If we examine this network we can see who is communicating with whom, and what kind of information is exchanged between participants. We can also analyze how many of those possible interactions or connections among participants exist, i.e., the extent to which all members of a particular network are interconnected. We hypothesize that, in a dense network, distributed expertise and students' cognitive diversity are better utilized for learning than in a very loose network of interactions.

Second, the participation and interactions should not be very centralized [19, 28]. By this, we mean that we should also consider whether the interaction in a CSCL environment is organized around particular participants; are there some central actors or isolated ones in computer mediated interaction or does the interaction distribute among many participants.

From this perspective, it is important to know the activity of participants --the proportion of all others with whom they communicate.

Third, the discourse should be reflective. There are many definitions of reflective discourse [29]. We, however, suggest that one particular but important aspect of reflective discourse be a part of effective discourse in CSCL environments: In order to discuss reflectively, students should not only provide more information related to others' contributions in discourse, but should also question others' arguments by asking clarification about their conceptions. Asking clarifications is essential, if students are expected to built and advance collective knowledge and understanding [29].

Fourth, the communication should be constructive [28]. If participants are constructive and give positive feedback to fellow students, it seems reasonable to presume that this will create a culture of constructive collaboration where students encourage each others' work. We do not mean that students should not be critical towards others' conceptions, on the contrary; but criticism should be communicated in a constructive way, avoiding negative and personal feedback. (The third obvious possibility is, of course, that the culture of collaboration is neutral; most of the exchanges do not contain either positive or negative feedback).

We do not argue that these four features we presented exhaustively define high-quality interactions and discussion in CSCL environments. However, we propose that these features are a prerequisite for reflective and progressive discourse, effective for learning both at the individual and collective level.

In this study we investigate how elementary class students participate in CSILE [Computer Supported Intentional Learning Environment, see 28] work, and the quality of their discourse. We are also interested in teacher's contribution to students' computer supported collaborative learning. Further, we explore whether our expansion of the concept of effective discourse has some empirical value, that is to what extent does students' participation and quality of discourse in some respects represent effective discourse we defined. To this end, we sought to understand the following:

- How dense is the communication within class?
- Is the interaction centralized or is it distributed among many participants?
- Who participates and to what extent?
- Are there participants who are in central or in isolated positions in the CSILE mediated communication?
- To what extent does the teacher participate?
- Is the discussion continuous or does it proceed along diverging lines?
- What is the quality of students' discourse?

Methods

Settings and participants

The present study was conducted in an elementary class in the city of Helsinki, during the years 1997-1998. The study is a part of a larger project that aims to develop and implement pedagogical practices and models of CSCL, and to analyze the cognitive and social aspects of CSCL in Finnish schools from elementary to university level. An important part of the overall research project is to carry out studies of CSCL in realistic settings, that is, in ordinary school environments [30].

The subjects were 21 students (10 girls, 11 boys), and one teacher from one elementary class. Students took part in the study on third grade (average age of 10 years) and on fourth grade (average age of 11 years). During the years 1997-1998, they undertook three intensive CSILE projects on topics, 'Energy', 'Map and environment', and 'Biological adaptation', and produced, in all, almost 700 CSILE notes. Students studied topics 'Energy' and 'Map and environment' on third grade. 'Energy' was studied and posted for a 4 week unit (6 hours per week) in autumn 1997, and 'Map and environment' for a 14 week unit (2 hours per week) in spring 1998. The topic 'Biological adaptation' was studied and posted for a 4-week unit (6 hours per week) in autumn 1998, when the students were on fourth grade. It was mainly the teacher who was responsible for selecting the topics and time of the year when projects were conducted. The topics for the CSILE projects were related to the curriculum. Further, the students were told that participating in CSILE work is considered as a part of their study credits.

Students used CSILE to facilitate open-ended student inquiry, in which generation of the their own research questions and theories, and search for scientific knowledge played an important role [for an informative treatment of student generated inquiry see, 29]. In study projects, students worked in pairs or in small groups on various subprojects under the main topic. In a typical project procedure the students made empirical experiments, worked with resource materials (books, Internet), engaged in classroom discussions with the teacher, and worked with CSILE. To foster collaboration and collective knowledge building students were encouraged to write their research questions, explanations and comments to CSILE, that is, to create CSILE entries called notes, for the good of the whole class. The present classroom was not equipped with computers. Thus, in order to use CSILE the teacher and the students had to go to a computer room.

The class was taught by a teacher who volunteered to participate in the study. She had three years of experience as an elementary school teacher, but was not familiar with ideas of computer supported collaborative learning or networked learning environments. For this reason, in the beginning of the study, she was introduced to CSILE work and to the practices of inquiry by the researchers. The researchers also helped her to plan the CSILE projects. In 1997-1998 the teacher participated in a 15 credit units special in science teaching, but otherwise had no intensive experience in that subject.

CSILE is a networked learning environment designed to facilitate collaborative knowledge building. CSILE provides opportunities for students to collaborate on learning activities by working through a communal database that has text and graphics capabilities. Within this networked learning environment, students create computer entries called notes that contain an idea or piece of information about the topic they are investigating. The notes can be labeled by categories, such as problem, my theory, or new learning that other students can search and comment on.

Data collection

School-based research, such as ours, has to deal with the fact that classrooms are complex learning environments where numerous factors and processes occur in relation to the other factors [31]. For that reason, we collected the data in the study using a multi-method approach: we used videotapes of students' learning processes during CSILE work, teacher and student interviews, students' responses to a self-report questionnaire on motivational orientation, and material from CSILE log files, an students' written productions from the CSILE database. In this paper we concentrate on analyzing the CSILE log files and students' written productions posted to the CSILE database [for the other analyses, see, 32, 33, 34].

Data analysis

In analyzing the data we utilized a combination of quantitative and qualitative methods, and various units of analysis. By using both qualitative and quantitative measures, we hoped to provide a comprehensive picture of elementary students' participation in CSCL.

Analysing participation: Social network analysis

We applied social network analysis to the CSILE log files. Log files provide researchers useful information for tracking students' participation in CSCL environments. From the log file information we computed the total number of notes, and received and sent comments for each student and teacher. Writing notes ('creating a note' and 'commenting) was chosen as an indicator of participation; although it may be possible for a whole class to benefit from reading notes written by couple of students it is more likely that learning will occur as more students become active participants and write notes [13; yet the evidence of the learning benefit of reading and writing in a computer mediated forums is still scant, see 35].

On the basis of the sent and received comments, the communication between participants (who is commenting to whom) was described in the form of a valued case-by-case matrix, which shows the actual relations among participants, and the strength of these relations; (for an example of a valued case-by-case matrix see Appendix A). In a case-by-case matrix the rows and the columns of the matrix represent the cases, for example, students.

There are two things to mention about relational data. First, it is important to understand, whether the relation is directed or nondirected, and secondly, whether it is dichotomous (binary) or valued. A relation is directional if the ties are oriented from one actor to another; for example, a student sends message to another student. In a nondirectional relation the tie between actors does not have a direction. A second property of a relation to consider is whether it is dichotomous or valued. Dichotomous relations are marked with only two values: 1, representing a present relation; and 0 representing an absent relation. For example, one could record whether one participant sent a comment to another; the relation can only take two values, 'send' or 'not send'. In valued relations the strength or intensity of each tie is recorded [37, pp. 47-50, 38, pp. 148-150].

We then analyzed the case-by-case matrix with social network analysis. The interactions among students during the projects were analyzed with a density test. Density describes the general level of linkage among the points in an interaction network. Students were viewed as points, and links between points (who is communicating with whom) as lines. The density of a network is defined as the number of lines in a network divided by the maximum number of all possible lines [37, pp. 72-73]. For instance, in a network of 21 participants (as in the present case), there are 210 (21x20/2) possible connections. Thus, the density of a network is complete, when all the points are connected to each other. The density value of a network varies between 0 and 1.

We also analyzed the centralization of students' interaction. While density describes the extent to which all members of a particular network are interconnected, centralization describes how tightly interaction within a network is organized around a particular focal participant or participants [38, p. 180]. Thus, density and centralization are complementary measures. In density and centralization measures the unit of analysis is the collective. These group level-measures give information about participation and interaction on the level of the whole network of CSILE mediated communication. The valued case-by-case matrix was dichotomized in density and centralization analyses.

To find the most central or isolated participants in the CSILE mediated interaction we calculated centrality values for each student and teacher by using Freeman's degree and betweennes. Degree and betweenness inform us about individual student's participation; they

identify who is a central or an isolated participant in a network. Degree measures individual participant's network activity, the proportion of all others with whom he or she communicates [37, p. 72, 38, pp. 178-180]. We treated received comments as indegrees, and sent comments as outdegrees.

A participant of relatively low degree may, however, play an important intermediary role in the network. Freeman's betweenness value shows how often a given participant is found in the shortest path between two other participants [37, 38]. In centrality measures, asymmetric data were used only in calculating degrees. In the case of betweenness we used symmetric data. Nondirected relations are always symmetric, that is, the top half of a case-by-case matrix is a mirror of the bottom half of the matrix. Valued data set can be symmetrized with various operations; in the present case the received and sent comments between a pair of participants were summed up [38].

The definition of who is active and who is inactive student in the class was made on the basis of percentile values: student was considered active if his or her participation rate was in the upper quartile and inactive if it was in the lower quartile.

Further, to analyze and visualize students' interaction we used multidimensional scaling (MDS). The input to MDS is usually a matrix representing relations between pairs of actors. Multidimensional scaling seeks to represent similarities or dissimilarities among set of entities in low dimensional space. Entities that are more similar to each other in the input data are closer in the space, and entities that are less similar to each other are farther apart in the space [38, pp. 385-387]. In other words, the basic idea behind MDS is that of using the concept of space and distance to map relational data

In order to analyze the continuity of students' discourse we identified note components (an example of a note component is provided in Appendix B). We use the term *component* instead of *thread*, because it perhaps more explicitly describes the way CSILE structures discussions. According to Wasserman and Faust [38 p. 109, see also 37], component is a graph in which the points are connected to each other through one or more lines. In other words, all points in a component, in this case, CSILE notes representing points, can reach one another through one or more lines. In addition, there is no line between a point in the component and any point not in the component. In the CSILE database, paths between notes are marked through hyperlinks. For example, a note created as a comment has an explicit hyperlink (path) to the note to which it refers. Components are mutually exclusive; a note belongs to only one component. We decided that the smallest acceptable component for analysis would have just two points. The social network analyses were executed with UCINET program [39].

Analysing quality of discourse: Content analysis

The quality of students' discourse was analyzed by qualitative content analysis [17, 40, 41]. The coding scheme was not predetermined but emerged and was refined through interaction with the data (for details of the classification see Appendix C. The classification is illustrated with excerpts from the present students' online conversations). Top-level notes (a note that starts a component) and isolated notes (a note that does not receive any response) were categorized with the following scheme: (1) Is the note a top-level or an isolated note, (2), Is the focus of the note on topic or off topic, and (3) Does the note ask a research question, provide information, or something else. Each comment was analyzed according to the following scheme: (1) Is the focus of the comment on topic or off topic, (2) Does the comment provide positive feedback, negative feedback or is it neutral, and (3) Is the function of the comment to provide information, ask clarification or something else. With these variables we could find out whether the students' discourse represents constructive and reflective discourse. In the content analysis comments were separated from top-level and isolated notes because comments

represent direct communication from one student to another. In other words, comment always has an explicit target.

Although any note could be composed of several ideas representing different categories of analysis, we decided the basic unit of analysis would be a note. This was because the notes were rather short and usually consisted of one or two sentences; it was very easy for the raters to find agreement concerning the classification. To validate the coding one rater coded the whole data, and a second rater separately coded 60% of the data. The interrater coder agreement in all categories was over 90%, which was considered satisfactory. Two student cases are presented in order to give reader a more detailed picture of the possible relationship between students' participation and quality of discourse in CSILE.

Findings and discussion

In this section, we report how students and teacher participated in computer supported collaborative learning, and how they interacted through CSILE. Aspects presented are density and centralization of interaction, individual participation rates, centrality measures of interaction, and the quality of discourse.

Findings on the patterns of participation and interaction

Density provides an indication of activity in the network - the extent to which class members are engaged in exchanging for example knowledge, opinions, advises, and feedback. The more students and teacher have connections with one another, the denser will be the network of interaction [38]. The density of CSILE students' network of interaction during the one and half year analyzed was .50, which is 210/420 of the all possible connection (for asymmetric data, i.e., the direction of connections considered). In other words, this measure showed that 50% of students collaborated through CSILE during years. The density value is rather high [26, 27]. However, in a small network, where the number of participants is low, the density value tends to be higher than in a very wide network; it is much easier to maintain many connections with a few people than with very many people. It is also possible that the number of connections within a network increases in the course of time, as might have happened in the present case. This hypothesis is supported by the densities of single projects; the density of 'Energy project' was .17, 'Map and Environment' .18, and in 'Biological adaptation' the corresponding figure was .27.

In a dense network, a large proportion of all the possible interactions among network members actually occur, information is distributed among many participants and members are likely to reciprocally influence each other. In a very dense network, however, widespread exchange of messages can lead to information overload. Hence, we do not yet know what is the optimal density of networks in CSCL environments for effective discourse and high-quality learning [19, 26].

Some previous research [27] showed that there might be a gender bias in CSCL communication. They showed that the density of interaction among male and female students was low indicating that boys mainly sent comments to boys, and girls sent comments to girls. We also measured densities within and among gender groups. Our results do not confirm the previous findings. Our analysis showed that students' CSILE mediated communication did spread equally among gender groups: the communication did not constitute any clique on the basis of gender, but girls commented actively boys' notes and vice versa, as the density values within and among gender groups show (see Table 1).

Table 1. Densities within and among gender groups

	Girls	Boys
Girls	.49	.46
Boys	.43	.51

We were also interested in whether the interaction through CSILE was organized around a particular focal student or students', that is, does the CSILE mediated interaction have a centralized structure. The analysis implied that the communication mediated by CSILE was not very centralized but was distributed among relatively many students. In the case of outdegree the centralization was 33%, and in the case of indegree it was 22% [see also 27]. The outdegree centralization appears to be higher than the indegree centralization showing that some students were more eager to make connections than others. In sum, the density and centralization measures showed that the CSILE communication not only spread among relatively many students but it spread also among genders.

The total number of notes that were responses to some other note (i.e., comments) was 348, which is 54% of all the notes posted to CSILE. The results of our study parallel these results; the previous studies indicate that the most common form of contribution in CSCL environments appears to be a comment [12, 13]. The high proportion of comments in CSCL environments appears to indicate that notes are very often addressed to a particular person and with particular purpose, instead being addressed to the whole community. It might also reflect the students' patterns of face-to-face interactions and conversational turn-taking. There were also notes that did not receive any response. The number of these isolated notes was 171, which is 27% of the total number of notes in CSILE database.

The CSILE discussion was composed of 126 note components, which ranged from 2 to 16 notes in length. The mean size of a component was 3.76 (SD = 2.62). The mean length of components shows that in an average note component there was a starting note (top-level note) and two to three responses. Generally, the discussion threads in on-line forums appear to be quite short [12, 13, 15, 25]. The high number of short discussion components indicates that the discussions might not be very highly connected but that they proceeded along diverging lines. According to Hewitt and Tevlops [15], the size of a discussion thread is important for continuous discourse. They further argue that the probability of thread's growth is related to the thread's size, and also to some degree, on the age of its notes.

Why then are components or threads so short? In the present case, one obvious explanation is that in many cases students of lower grade levels are not necessarily fluent writers and readers, and might have difficulties to participate in forums that require them to express their thinking in written form [24, 42] This might restrict the activity and quality of their participation. Secondly, a threaded discussion is time- and effort- consuming to follow [18, 23]. A large number of messages in the database can make it difficult to follow the discussion, and get an overview about issues being discussed. Thus, while working with CSILE, both teacher and students might have faced substantial knowledge management problems. It is possible that this also hinders the making of contributions.

To date, we have mainly discussed about structural threads, that is, how the CSILE system organizes discussions. This point of view gives, however, too narrow picture of CSCL discussions. Future research is needed to determine the value of "conceptual threads". By conceptual threads we mean notes that are semantically or conceptually linked to each other. An example of a conceptual thread (or a conceptual component) would be all the notes posted

to solve some particular research question or problem-solving task. This approach might be fruitful when assessing what students have really learned or whether some mediating conditions for effective discussion have been met.

The total number of written notes was conceived as an indicator of students' participation activity. Through the years 1997-1998 students produced, in all, 645 CSILE notes. All the students in the class used CSILE to some extent. Despite of the rather high density and non-centralized nature of interaction, students engaged in CSILE work with different levels of activity, some being very active and some inactive (see Table 2).

Table 2. Students' participation rates

Student	Gender	Total # of notes Includes sent comments, top-level and isolated notes M = 30.71 SD = 10.91 Percentile Value 25.00 20.50 50.00 31.00 75.00 40.00	Total # of top-level and isolated notes M = 14.14 SD = 4.07 Percentile Value 25.00 11.00 50.00 13.00 75.00 16.50	Total # of outdegrees (sent comments) M = 16.57 SD = 8.45 Percentile Value 25.00 8.50 50.00 17.00 75.00 22.00	Total # of indegrees (received comments) M = 16.57 SD = 4.93 Percentile Value 25.00 12.50 50.00 16.00 75.00 20.50	Freeman's betweenness M = 3.24 SD = 1.82 Percentile Value 25.00 1.53 50.00 2.63 75.00 4.93
1 Ulla	f	30	13	17	25	3.97
2 Tiina	f	32	14	18	14	2.42
3Erkki	m	18	12	6	9	1.47
4 Pasi	m	50	23	27	21	4.63
5 Tapani	m	16	8	8	14	0.95
6 Kirsi	f	46	13	33	16	4.72
7 Liisa	f	38	17	21	19	5.49
8 Minna	f	40	13	27	23	5.14
9 Jussi	m	40	22	18	15	6.04
10 Sami	m	23	12	11	21	2.53
11 Pekka	m	15	11	4	11	1.60
12Matti	m	47	16	31	19	6.28
13 Juha	m	34	11	23	10	3.87
14 Ilona	f	23	10	13	16	2.40
15 Mika	m	24	15	9	13	1.36
16 Tiia	f	17	11	6	16	1.27
17 Simo	m	31	14	17	17	5.58
18 Siru	f	31	13	18	26	2.81
19 Emmi	f	32	18	14	12	2.63
20 kari	m	41	21	20	20	2.56
21 Silja	f	17	10	7	11	0.29
Total		645	297	348	348	

As documented in Table 2 students wrote between 15 and 50 notes with an average of 30.71 notes (SD = 10.91). Six students, Pasi, Kirsi, Jussi, Minna, Matti and Kari did engage actively in CSILE work, and wrote 50, 46, 40, 40, 47, 41 notes, respectively, which is as much as 41 % of all the notes students posted to CSILE. The most inactive participants were Erkki, Tapani, Pekka, Tiia, and Silja (18, 16, 15,17, 17 notes, respectively).

A positive result was that participation was rather broad based - all students participated to some extent. As reported by Guzdial and Turns [13], the participation ratio (i.e., the ratio of the

authors in the discussion forum to the number of students in the class) in courses using collaborative technology seldom appears to be 100%, at least at the university level.

In order to analyze individual students' position in the CSILE mediated interaction, that is, whether someone is central and non-central actor in the CSILE mediated communication, we calculated a centrality value for each student by using Freeman's degree and betweenness measures. Students' outdegrees (send comments) varied between 4 and 33 (M = 16.57, SD = 8.45) comments, and indegrees (received comments) between 9 and 26 comments (M = 16.57, SD = 4.93). As the rather high standard deviation values in outdegrees and indegrees demonstrates, students not only engaged with very different intensity in sending comments but they also received very different number of comments (see Table 2).

Every student sent comments and also received comments. Pasi, Kirsi, Minna, Matti, and Juha had the highest outdegrees (27, 33, 27, 30, 23, respectively) and five students, Erkki, Tapani, Pekka, Tiia, and Silja had low outdegrees (6, 8, 4, 6, 7, respectively). High outdegree indicates that student actively creates connections to the other members of the network.

High indegree demonstrates that others are, for some reason, very often contacting this particular student. This might indicate, for example, that the nature of her or his notes and comments is in some way interesting or remarkable from others point of view or that the student is a popular in the class. The low indegree indicates that a particular student as a person, or his or her work, is not interesting from others perspective. Ulla, Pasi, Minna, Matti, Siru had the highest indegree values (25, 21,23, 21, 26, respectively) and Erkki, Pekka, Juha, Emmi, and Silja had low indegrees (9, 11, 10, 12, 11, respectively). Students who have a high degree (indegree and outdegree summed) have most connections to others and conversely. Four students, Pasi, Kirsi, Minna, and Matti had a high degree, and Erkki and Silja had vey low degree. In some cases a high outdegree or indegree value may also be a consequence, for instance, of very intensive communication between two or three authors. Merely the interaction among few students might make them very prolific and central actors in the network of interaction [25].

Betweennes value informs about participant's centrality in the interaction network [38]. Four students, Liisa, Minna, Jussi, Matti and Simo, had high betweenness value indicating that they were in central position in the network of CSILE mediated interaction. As opposite, five students, Erkki, Tapani, Mika, Tiia, and Silja had low betweenness value (see Table 2).

Put brief, centrality measures demonstrated that students had very different positions in the network of CSILE mediated interaction, some of them having a central, and others even isolated position. Only one student, namely Minna, had a high value in all the dimensions analyzed - total number of notes created, outdegree, indegree, and betweennes. Perhaps we are justified in concluding that Minna was the most visible and prolific author in the CSILE mediated communication. By contrast, there were two students, Erkki and Silja, who made relatively few contributions to CSILE mediated discussion, and had low value in all the measured dimension indicating an isolated position in CSILE mediated interaction. This clearly is important information for the teacher; something needs to be done in order to get the isolated and inactive students more actively involved in the CSILE work.

Researchers have lately expressed concerns about the low level and uneven participation in CSCL environments [13, 23]. Concurrently, however, they seem to ignore the fact that uneven distribution of participation and passive behavior in public discourse are not only problems in CSCL environments, and online forums in general, but also in the traditional classroom learning process and discussion too. Admittedly, we should be worried about these topics, and especially, because the implicit promise of CSCL has been that it will democratize the participation of students. In fact, our raw data (videotape of the present students' and teacher's discourse processes in classroom without computers) show that the oral classroom interactions

are more centered on the teacher than the discussions in the CSILE environment. The teacher had much higher outdegree and betweenness values measured during traditional classroom interaction than in CSILE work, indicating her central position in the network of interaction in traditional classroom learning. In contrast, students had many fewer connections with each other during oral classroom interaction than during CSILE work.

Figure 1 represents the multidimensional scaling concerning students' interaction pattern. The interaction was used as a measurement of similarities: the more messages the participants sent or received from certain students, the closer they are situated in the three dimensional MDS map [31, 38]. The stress value, a measure of the quality of the MDS map, was at an acceptable level, 0.14 (stress values below 0.1 are excellent and above 0.2 unacceptable, [39]. As we can see in Figure 1, most of the students are rather close to each other in the MDS map indicating that they have sent and received comments from each other rather equally. However, two students, Pekka and Silja appear to be outsiders.

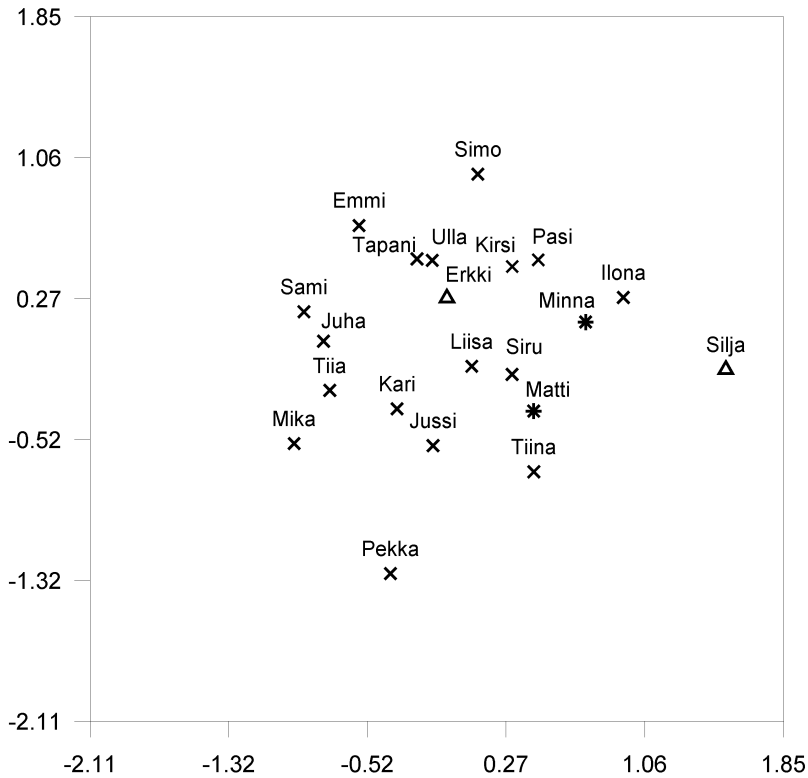

Figure 1. Pattern of participation on the basis of multidimensional scaling (MDS)

✷ Student with a high degree and a high betweenness value

Δ Student with a low degree and a low betweenness value

Findings on the quality of discourse

The length of note components seemed to have impact on the quality of the students' discourse. The nature of students' comments is documented in the Table 3. Of the comments participants send to each other 52% were on class-learning topic, and 48% off topic. But if we consider all the notes students posted to CSILE database the proportion of on-topic notes was 72% and off -topic notes was 28%. This is because the top-level and isolated notes were extremely topic oriented (see Table 4).

Table 3. The quality of students' comments

Focus of comments	**Frequency**	**Percent**
On topic	181	52
Off topic	167	48
Total	348	100
Nature of comments		
Positive feedback	76	22
Negative feedback	58	17
Neutral	214	61
Total	348	100
Function of comments		
Providing information	178	51
Asking clarification	71	20
Other	99	29
Total	348	100

Table 4. The quality of students' isolated and top-level notes

Focus of isolated and top level notes	Frequency	Percent
On-topic	282	95
Off-topic	15	5
Total	297	100
Function of isolated and top-level notes		
Research questions	39	13
Providing information	244	82
Something else	14	5
Total	297	100

First we were little disappointed, especially with the nature of comments; we had expected the discourse to be more oriented on the subject matter and practices of inquiry than it actually was [14]. We thought that the more the discussions would be oriented towards learning topics the more students perhaps would learn. But would a discussion focused totally on learning topics be a realistic goal? It might be true that off-topic discussions are not valuable for learning. But if this off-topic communication represents, for instance, mainly positive or neutral social discussion as it did in the present case, then it might serve important functions, such as activating participation in discourse, increasing motivation, and building a community. Be it a virtual or non-virtual community, to be effective in building collective knowledge, it must have, for example, shared values, narratives, and shared sense of humor [43]. In fact, we do not know what is the optimal proportion of off-topic communication and on-topic communication for effective discourse and collaboration. Instead of ignoring the possible impact of social discussion, we should ask, How is social-oriented discourse related to explanation-oriented discourse and community building. Comments that were off topic were mainly focused on social issues such as greetings. Sometimes students also expressed verbal bullying on a personal level.

Of those comments that were on topic 62% were providing information and explanations, and 38% were asking clarification. This demonstrates that while commenting on the topic participants mainly appeared to answer each other's questions and to provide more information for fellow students inquiry. Can this type of discourse be considered reflective? We do not want to deny the importance of answering to others questions or commenting on others notes by providing new information and explanations; it is evidently an important part of effective discourse. This type of discourse pattern is not enough, however. In a reflective discourse students should not only be seeking understanding by offering answers and explanations, but also by requesting clarifications concerning fellow students' questions and theories in order to better understand the thinking of other members of the learning community [28, 29]. Perhaps,

in order to represent genuine reflective discourse, students should have been asking more clarifications in the course of CSILE mediated knowledge construction. Moreover, in reflective discourse the length of discourse components should be longer; there is little hope for reflection if the average depth of discourse is only a few steps.

There is one more aspect in the quality of students' CSILE discourse that deserves discussion. Contrary to what might be expected, there were never real heated discussions with students negotiating meaning or taking sides of issues [see also 14] - the proportion of neutral comments was rather high (61%). As we stated in the introduction section, positive feedback would be an indicator of a constructive communication, a part of an effective discourse. However, in only a very small number of comments did students really express positive feedback. What was encouraging is that the proportion of negative comments (17%) was very small; even smaller than the proportion of positive comments (22%).

How should we account for this neutrality of communication, especially from the perspective of constructive discourse? This genre does not represent "pure" constructive discourse defined earlier, but it does not either represent deconstructive communication. One thing seems obvious; it is easier to turn the students' neutral style of communication to positive discourse than change the genre of communication from negative to positive. From students' point of view the neutral comments may even be interpreted as encouraging. In addition, we do not know whether this neutrality of communication reflects broader institutional norms of communication, for instance, that one should be pertinent in discussions, or whether it reflects just following the teacher's lead or her orders. Or perhaps it is merely a sign of students' shyness or caution? These are issues for which we do not have an answer and thus should be studied in the following studies. Put briefly, we can define the culture of CSILE communication as follows; on topic, neutral, and providing information to others comments or questions.

What then was the quality of an individual student's notes? Does the quality of notes in any sense explain student's visible or isolated position in the CSILE mediated interaction? In the following, we explore more closely two cases, namely those of Minna, who was the most visible student in the CSILE mediated communication, and Silja, who appeared to be in an isolated position in the network of interactions.

Minna created 40 notes; of these notes 71% were on topic and 29% were off topic. Minna had a high outdegree, and sent comments to 12 classmates (only three students had higher number of contacts than Minna). She received comments from 12 students (only 2 students received comments from higher number of classmates). Why then were others interested in Minnas's notes? Her high indegree might be, at least partly, a result of her own activity, that is, a consequence of the high number of notes she sent. If one is communicative and sends many comments one also has a chance to receive many replies; we might expect that a mutual relation between sent and received comments would emerge. Of the comments Minna created 63% were on-topic and 37% off-topic notes. It seems plausible to conclude that others were not interested in Minna's notes mainly for the sake of the information they contained. One explanation for the others interest in Minna's work would be that the proportion of Minna's positive comments was very high (52%); It seems that Minna performed constructive communication and really did support her classmates work through CSILE (e.g., "It is great that you have informed us about those Internet links! Good idea! Carry on!"). On the other hand, Minna is a popular and active student in the class; for that reason she might have been popular in the CSILE mediated discussion too.

Our second case was Silja, who was an inactive student, and appeared to be in an isolated position in the network of CSILE mediated interactions. The first thing that drew attention is that Silja created only 7 comments to CSILE database, and perhaps as a consequence, also received only 11 comments. We do not know why there were so few notes, and the following

are some questions for which we do not have an answer: Is Silja to be considered as a "free rider", who off-loads cognitive responsibilities for others? Or did she find that participating in CSILE work would be a good way to learn? Did she work more outside of CSILE? Interestingly, the quality of notes Silja's posted to CSILE was extremely high; 94% of them were focused on topic (e.g., "How did you design your experiment?"). If the criteria for other students' interest in her notes would have been only the quality of notes then Silja would probably have received more response.

Both cases, Minna and Silja, implied that students' position or visibility in the CSILE mediated discourse is only partly based on the subject-related quality of their notes and their own activity; other factors that might have had impact are friendships and student's popularity in the class, as well as his or her motivation to participate [33]. These two cases showed in more detail that there are differences, not only in the students' participation activity, but also in the quality of their participation in CSILE mediated discourse.

How did the teacher contribute to students CSILE mediated communication? During the one and half years analyzed, teacher created 33 notes. All the notes she posted to CSILE were comments, which indicate that the notes were addressed for particular students, and perhaps, with particular purposes. Teacher also had more sent than received comments, which seems plausible if one is expected to be a facilitator of learning processes. Through the years studied the teacher sent comments to 20 students (n=23), and received 8 comments from 8 students. To find out her position in the CSILE mediated knowledge construction, we calculated also betweenness value including teacher in the analysis. She had a high betweenness value, 5.75. The high value points out that she occupied quite special position in the network of interactions within the CSILE mediated communication. These measures are in line with some earlier observations [12, 19]; the teacher (or tutor) is commonly very prolific author, and in the central position in the network of computer mediated interactions.

We can say that the teacher participated rather actively in students' CSILE-mediated discourse. Her comments (see excerpts 1, 2, 3) were supportive; she requested students to do some more research; she did not produce direct answers nor direct guidance; instead the objects of her comments were students' intuitive conceptions, as she tried to guide them in monitoring the progress of their discourse and understanding.

Excerpt 1.

Teacher: What do you mean when you write that energy is power? Could you explain this issue?

Excerpt 2.

Teacher: Good note. But is energy really matter? If it is, what kind of matter do you mean?

Excerpt 3.

Why then does lynx have tufts on its ears?

Yet, her comments appeared to have little effect on students' work; students did not respond actively to her comments by conducting further episodes of inquiry. It appears that her strategy was to pose questions in order to get students to do some research. According to the thinking of Ahern and others [10], this might not be the best strategy for promoting participation. They described three types of teacher discourse in computer-mediated discussion: question-only, statements-only, and conversational, and suggested that the conversational discourse type is

likely to produce greater participation and more complex student interaction. It might also have been the case that the teacher did not emphasize the importance of responding to her own and the others' notes in the beginning, and did not check enough whether it was done. We do not yet know how much, and what kind of involvement is need from the teacher in order to keep discussions active, and high in quality.

What appears to be in common to the most successful CSCL experiments is that an enthusiastic and knowledgeable teacher is working in a well-equipped environment and is strongly supported by the researchers and technical aids [44]. Yet several development projects have also shown that it is difficult for even very experienced teachers to adopt and apply new, advanced pedagogical methods [45]. To be able to work effectively with CSCL, and to implement modern cognitive ideas, many teachers have to achieve a substantial shift in their pedagogical and epistemological practices. To success teachers might need a great deal of pedagogical and epistemological support from researchers, and also practical knowledge of good approaches.

Conclusions and recommendations

The aim of the present study was to investigate elementary students' participation patterns and quality of their discourse in the CSILE mediated communication. Our central goals were to analyze whether our expansion of the concept of effective discourse has some empirical value, and to what extent does students' participation activity and quality of discourse in some respects represent effective discourse.

By combining qualitative content analysis and social network analysis, the study presents new methodological possibilities to analyze participation and discourse processes that take place in CSCL environments, and in electronic forums in general. Social network analysis appeared to be especially appropriate for collective-level analysis such as studying structural and relational data such as relationships and interaction processes that go on beyond single participants. Applying social network analysis one can demonstrate, for example, how information, ideas, and advice circulate in a network [19, 26]. Social network analysis brings out interesting interaction and participation structures, which then can be analyzed further with qualitative content analysis. Other strength of the study is that it was based on a data from a rather long period.

Our data and analysis are to be considered more as effects with CSCL - the analyses were not dealing with effects of CSCL, that is, whether the active or inactive participation and quality of discourse were related to learning outcomes [4]. Thus, what individual students did perhaps learn, go beyond the scope of the present study. The present study, however, gives information about participation and discourse patterns that might limit or promote learning in CSCL environments. In the future analysis we will compare students' interaction in the classroom and their interaction in the networked learning environment, and will also interview students and teachers about their participation.

Our idea of the concept of effective discourse (originally defined by Guzdial and Turns) proved to be useful. Conceptually it brought out important and useful features of participation and interaction processes that emerge in CSCL settings, such as density and centralization. In addition, analysis showed that the concept could be operationalized and explored empirically. However, further research is clearly needed to establish the idea of effective discourse, both conceptually and empirically.

Put briefly, the research reported here and other investigations [12, 13, 15, 23] show that regardless of the educational level there is often a lack of sustained, connected and high-quality discourse in CSCL environments. On the basis of these studies we can conclude that many issues remain to be addressed in realizing the educational potential of computer-

supported collaborative learning. There is a great need of methods for enhancing participation and interaction in CSCL environments.

What has been learned from the research conducted on computer supported collaborative work is that collaborative technology will enhance participation in an organization when organization members have a genuine need and desire to collaborate; when users understand the technology and how it can support collaboration; when the organization provides appropriate support for the adoption, implementation, and continued use of the technology; and when organizational culture supports collaboration [46]. Perhaps researchers and teachers should stress these aspects more also in classroom context.

Many CSCL environments provide no other form to represent knowledge than the forum's text notes. In addition to writing, collaborative representation tools such as advanced visualization, simulation and modeling tools are needed. They offer students a possibility to construct richer interchange of graphical and written representations [42]. Further, anchoring tools, such as prompts of suggested activities or external Web pages, can help to address the issues of why get involved in a discussion, and how does one discuss [13]. All these tools would help students with limited writing skills to participate more actively and productively, and to overcome the knowledge management problem, commonly observed in threaded discourse. Other factors that might facilitate participation and interaction in CSCL environments are promoting alternative views for students to discuss, anchoring discussions to students' personal experiences, option to make anonymous contributions, offering interesting and timely topics, making online discussion a part of legitimate classroom activity, and alternating face to face and electronic discussions [47, 48].

Yet, little attention has been given to the technical support for inducing and enhancing participation and interaction in collaboration. Collaborative agents and other entities based on artificial intelligence can provide significant support for collaboration. These intelligent agents may, for instance, make a learner aware of someone who has the same problem or knowledge as the learner, who has a different view of the problem or knowledge, and who has potential to assist him or her in the problem solution. In addition, intelligent agents can give information about activities that a participant conducts in a shared workspace, indicating, for example, when someone is looking at the same knowledge that one is looking at. These tools can help manage a relatively large number of messages in databases, handle the threaded structure of discourse, and also facilitate community building [49].

Active participation in CSCL is not enough, however. What should also be promoted is the quality of discourse. This is not easy, as also this study showed. We think that there is one central factor in promoting high-level discourse, namely teacher's scaffolding. Teacher is needed to structure learning events and the discourse, to give advice and feedback when needed, verifying and clarifying students' understandings, raising students' awareness about the nature and focus of their communication, and prompting active participation [50, 51]. What makes scaffolding difficult is that there may not be general rules for scaffolding in order to achieve high-quality discourse; scaffolding may be highly situated and context depended activity. If this is the case, then scaffolding procedures have to be rebuild in new situations. Hence, things to be considered in scaffolding include, students with whom the teacher works, the technology that is used, teacher's own resources, and the culture of learning. Evidently, more research is needed on scaffolding in CSCL - most of the CSCL studies have been concentrated on students' learning processes; teacher's role is seldom investigated area.

This study provides one example of computer supported collaborative learning studies, and shows that elementary student have the potential to engage in effective computer supported collaboration. Simultaneously, this study challenges CSCL researchers and teachers to find ways to support equal and active participation and high quality discourse in CSCL environments.

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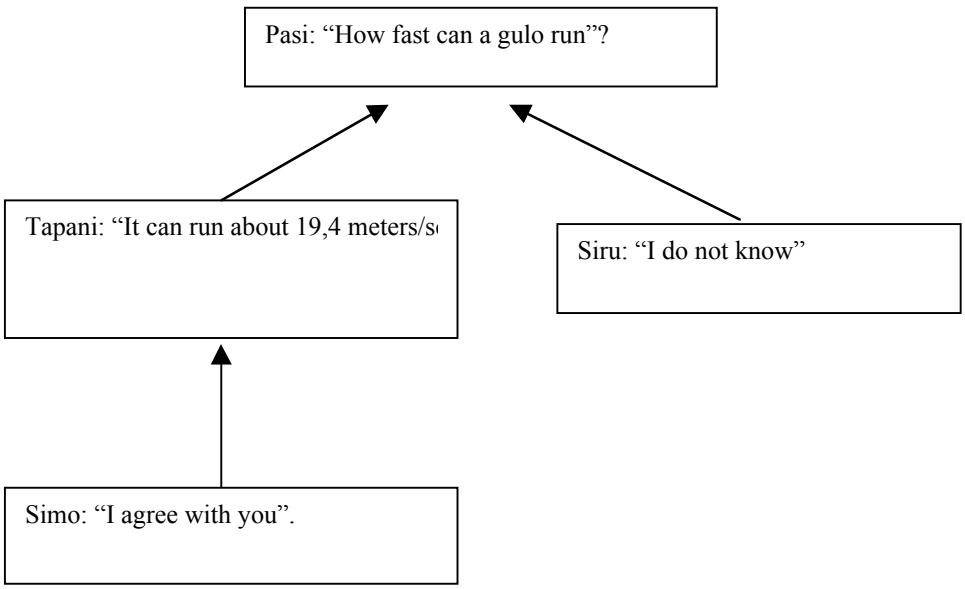
Appendix A. An example of a directed and valued case-by-case matrix.

Rows and the columns of the matrix represent participants (cases), and values represent, for instance, sent and received messages.

Participant	A	B	C	D	E
A	-	3	2	4	2
B	2	-	3	2	1
C	3	2	-	2	2
D	1	1	1	-	1
E	4	3	4	2	-

Appendix B. An Example of a note component.

The direction of the arrow shows the target note of the comment. The component (thread) represents the present students' online conversation.



Appendix C. The coding scheme for analyzing the quality of notes posted by the participants to CSILE database.

The excerpts in the brackets are taken from the present students' online conversations.

Top-level and isolated notes

Isolated and top-level notes were analyzed according to the following scheme:

Type of the note

Top-level note. The note starts discussion.

Isolated note. The note does not receive any response.

Focus of the note

On topic. The focus of the note is on the class-learning topic or on the practices of inquiry (e.g. "What is mammal?").

Off topic. The focus of the note is any other than class-learning topic or practices of inquiry (eg. "Blame yourself, and don't bawl me out.").

Function of the note

Asking research question. (e.g. "What does a bear eat.").

Providing information. (e.g. " Bats are mammals.").

Something else. (e.g. "Hi everybody.").

Comments

Comment were analyzed according to the following scheme:

Focus of the comment

On topic. The focus of the comment is on the class-learning topic or on the practices of inquiry (e.g. "You posed a good research question.").

Off topic. The focus of the comment is any other than class-learning topic or practices of inquiry (e.g. "Hello, how are you doing.").

Nature of the comment

Positive feedback. The comment encourages the receiver (e.g. " That was a very good Internet link you send me.").

Negative feedback. The comment is unconstructive ("e.g. You are stupid.").

Neutral. The comment cannot be classified either of the two previous categories (e.g. "Bear and rabbits are mammals.").

Function of the comment

Providing information. The comment provides information concerning the class-learning topic or practices of inquiry (e.g. "Bear and rabbits are mammals.").

Asking clarification. The comment asks clarification concerning the class-learning topic or practices of inquiry (e.g. "How did you design your experiment.").

Other. The comment cannot be classified either of the two previous categories (e.g. "Be quiet, you are stupid.").