Patterns of participation and discourse in elementary students’ computer-supported collaborative learning

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Abstract

The goal of the investigation was to analyze patterns of participation and discourse mediated by Virtual Web School (VWS). Twenty-three fifth-grade students participated in the study. The findings showed that the density of interaction among participants was high, and all the participants used VWS to some extent. There were, however, substantial differences in the participants’ participation activity and their position in the network of VWS-mediated interaction. The study also showed that the VWS-mediated discussion was not sustained, but instead comprised a number of short discussion threads. Although over half of the participants’ postings were focused on class-learning topics, much needs to be improved in the quality of their discussion.

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1. Introduction

The issue of how collaborative learning supported by technology can enhance peer interaction and work in groups has attracted considerable attention in recent years. This area of research is referred as computer-supported collaborative learning (CSCL). CSCL and CSCL applications (for a review, see Lehtinen, Hakkarainen,
Lipponen, Rahikainen & Muukkonen, 1999) offer prerequisites for socially mediated and distributed learning, and give students the opportunity for more effective interactions and participation than in a traditional classroom setting. CSCL environments offer a medium for classroom discussions that may facilitate participation and social interaction among students, and between the teacher and students (Koschmann, Hall & Miyake, 2001; Lehtinen et al., 1999). As a consequence, the use of CSCL has become, at present, an important part of students’ activities in some better equipped classrooms.

There is a body of empirical evidence indicating the benefits of CSCL. Findings of several studies in classrooms receiving intensive teacher and student support may be summarized as follows. CSCL is reported to facilitate task-oriented and reflective activity (Cohen & Scardamalia, 1998; Hakkarainen, Lipponen, Järvelä & Niemivirta, 1999), complex reasoning and levels of argumentation (Hoadley & Linn, 2000), progress in use of conceptual models (Bell, 1997), mathematical problem solving (Enyedy, Vahey & Gifford, 1997), and the learning of complex scientific concepts (Roschelle, 1992). Evaluations comparing CSCL and non-CSCL students revealed that CSCL students outperform non-CSCL students on standardized achievement test scores in mathematics and in reading (Lamon et al., 1996). Among other cited educational advantages of CSCL it is argued that it supports collaborative knowledge building and inquiry practices, such as engagement in increasingly deeper levels of explanation, progressive generation of subordinate questions, and collaborative effort to advance explanations (Edelson, Gordin & Pea, 1999; Hakkarainen & Sintonen, 2002; Lipponen, 2000; Scardamalia, Bereiter & Lamon, 1994). In a similar vein, CSCL is reported to increase students metacognitive understanding (Brown, Ellery & Campione, 1998; Cohen & Scardamalia, 1998), and to support distributed design processes (Seitamaa-Hakkarainen, Raami, Muukkonen & Hakkarainen, 2001).

Although a number of studies on CSCL have demonstrated promising improvement in learning results, both on individual and collective levels, the empirical research has also revealed disadvantages of CSCL. Guzdial (1997) and Guzdial and Turns (2000) studied 35 university-level electronic conferences, and discovered that on an average, students wrote only 4.8 notes (messages) in total, for the 10-week period. Hara and others (Hara, Bonk & Angeli, 2000) conducted a study among graduate-level students using CSCL, and found that students wrote on an average 15 notes per student during the entire 15-week course. Hsi (1997) studied eighth graders and discovered that students wrote an average of 4.82 notes during 18 weeks. Several other studies (Davis & Huttenlocher, 1995; Hewitt & Tevlops, 1999; Hoadley & Linn, 2000; Howell-Richardson & Mellar, 1996; Lipponen, 1999; Muukkonen, Hakkarainen & Lakkala, 1999; Nurmela, Lehtinen & Palonen, 1999; O’Neill, Edelson, Gomez & D’Amico, 1995) support these findings; students do not participate (where ‘participation’ is defined as writing notes) very intensively in certain types of CSCL environments (for instance, where the teacher is not especially committed and supported).

Another disadvantage of CSCL, in addition to the low level of participation, appears to be that most of the discussion threads in CSCL environments are very short, containing only a few contributions (Guzdial, 1997; Guzdial & Turns, 2000;
Hewitt & Tevlops, 1999; Lipponen, Rahikainen, Hakkarainen & Palonen, in press). Guzdial (1997) and Guzdial and Turns (2000) found that the average size of a thread in CSCL discussions was only 2.8 notes. Hewitt and Tevlops (1999) (see also Hara et al., 2000) found similar results in a study among nine university courses; the mean length of a discussion thread was only 2.7 notes. Lipponen et al. (in press) discovered that the mean size of a discussion thread in elementary students’ CSCL interaction was 3.8. These studies indicate that in many cases discussions in CSCL environments are not sustained, but proceed along diverging lines.

The evidence whether students’ discussions in CSCL environments are focused on class learning topics or on social exchange, and what would be an optimal proportion of these two for learning, is still controversial. Several researchers (Bonk, Malikowski, Angeli & East, 1998; Guzdial & Turns, 2000; Hara et al., 2000; Lipponen, 2000) have reported that discussion in their CSCL environments tend to be focused on class learning topics. However, Stahl (1999, in press) has pointed out that CSCL environments are mainly used for exchange of personal opinions, and for delivering surface knowledge, not for collaborative knowledge building. Consistent with Stahl, the report of Feldman et al. (2000) concluded that most of the messages posted in public discussion spaces appear to be social in nature.

The results of the studies conducted under the label of CSCL are difficult to compare, because they differ from each other in aspects such as instructional design applied, teacher preparation and commitment, technical support for the teacher and students, technologies used, and how some particular applications were used. A detailed analysis of the comparability of different CSCL environments is beyond the scope of this paper.

The advantages and disadvantages of CSCL appear to be widely debated, hence, there remains a need for more research to further inform these debates and help resolve the issues. For instance, there is only a small number of academic publications concerned with issues such as whether particular students dominate CSCL discussions, or who is communicating with whom, or to what extent communication through the CSCL environment is interconnected (but see, Haythornthwaite, 1999; Lipponen et al., in press; Nurmela et al., 1999; Palonen & Hakkarainen, 2000). To date, there have been only a few attempts to analyze students’ position in CSCL mediated interaction (Lipponen et al., in press; Nurmela et al., 1999). The previous research, moreover, does not combine the quantitative (participation rates) and qualitative aspects (continuity and nature of discourse) of participation. In addition, previous studies on CSCL and participation have mainly been conducted at the university or high school level, and there are few extensive descriptions of how elementary students participate in CSCL.

The socio-cultural theories of learning constitute the framework of the present study. In the wider framework of the socio-cultural tradition, human activities are seen as socially mediated and, thus, learning is seen more as a matter of participation in a social process of knowledge construction than as an individual endeavor (Greeno, 1997; Vygotsky, 1978). Knowledge emerges through the network of interactions and is distributed among those (humans and tools) interacting. Following this line of thought, we can say that participation and discourse become the key
concepts of learning, as contrasted with acquisition (Sfard, 1998). As stated by Lave and Wenger (1991), learning is a process that takes place in a participation framework, not in an individual mind.

We are just beginning to understand the participation and discourse processes occurring in CSCL environments and still lack information required to answer such questions as:

- To what extent are all participants of CSCL mediated communication interconnected (i.e. what is the density of interaction)?
- Is the interaction centralized or distributed among many participants?
- Who participates and to what extent?
- Are there participants who have a central or an isolated position in the network of CSCL-mediated interaction?
- Is the discussion sustained or does it proceed along diverging lines?
- What type of knowledge is exchanged through CSCL?
- Who is communicating with whom?

2. Methodology

2.1. Design of the study

The present study took place in a suburban elementary school district in the city of Helsinki in spring 2000. The subjects were 23 fifth-grade students (12–13 year-olds), 11 girls and 12 boys, from one elementary school class. The 23 students were not novices in using educational technology, but had two years of experience of working with Computer Supported Intentional Learning Environment (CSILE, see Scardamalia & Bereiter, 1994).

The topic that the students studied was ‘Human senses’. It was conducted as a 4-week unit, 6 h per week. Students worked individually (four students: Kari, Sami, Erkki, Simo), in pairs (five dyads: RiAn, TaOs, SiNi, TiTe, EeSa), and in triads (three triads: InJuKa, JoMiOt, SoSaEl; hereafter, an individual student, a dyad or a triad is referred to as a participant; thus overall there were 12 ‘participants’). This assignment had been chosen by the teacher and the students. Within the project the students worked on various subprojects (sense of smell, taste, feeling, hearing and eyesight), with the teacher selecting the topics. In addition, the teacher made students aware that participating and contributing to VWS-mediated learning was part of their normal school work and study credit.

This type of natural study design (i.e. the students did not create notes individually, and did not work in the groups of the same size) is very common when a researcher works in realistic settings—in ordinary school environments, and not in laboratory with carefully controlled experiments. Hence, the design can be considered ecologically valid. It can be seen that there is a trade-off between rigour of design and ecological validity, and no perfect solution exists. Furthermore, for instance a dyad or a triad can be viewed as comprising two or three relatively independent cognitive
units, but they can also be viewed as a single cognitive unit with its own properties (Dillenbourg, Baker, Blaye & O’Malley, 1996, p. 190). In addition, because of the small amount of each participant type (single, dyad, and triad), and abnormal distribution of the measure (number of notes), the statistical significance of the differences was examined using non-parametric version of the analysis of variance (Kruskal–Wallis test). According to the analysis, there were no significant differences between the different participants with regard to the number of written notes.

The instructional unit had several phases. During phase 1, the teacher created a context for the learning process and guided the students in generating research questions for the learning topics, asking for instance, “Tell me what do you wonder about human eyesight?” This phase was conducted as a whole-class discussion. During phase 2, students were asked to answer their research questions, constructing explanations on the basis of their prior knowledge. In phase 3, students were instructed to assess the explanations they had generated or test them empirically. In phase 4, they were tutored to search for new scientific information using books and the Internet for the improvement and refinement of the prior explanations. To facilitate collaborative knowledge construction, students were encouraged to post their research questions and explanations to VWS, and to comment there on others’ work in order to give and receive assistance and feedback. Hence, the aim was to share all aspects of the instructional unit from setting up of research questions to information search through the VWS environment. There is one thing to remember. The depicted instructional unit must be taken as a general model, because inquiry is never a linear process, but more of an endless activity to advance individual and collective knowledge (see Koschmann, Kelson, Feltovich & Barrows, 1996). For example, in many cases the construction of research questions and generation of explanation for resolving them feeds the genesis of new questions and explanations.

The class was taught by a teacher who had four years’ experience as an elementary teacher. She started working with these students in autumn 1999. This study was her first attempt to use a CSCL environment to support learning activities. Further, a characteristic of the Finnish teaching profession at the elementary level is that teachers are rarely subject–matter experts. Instead, they teach many subjects, such as reading and writing, biology, mathematics and environmental science.

The Virtual Web School (VWS, http://mauri.edu.hel.fi/) is an Internet-based asynchronous bulletin board system for storing and sharing information. VWS supports asynchronous discussions, and automatically keeps track of the discussion threads, that is, the forum records and represents which notes are replies to which other notes (see Appendix A). Students use VWS by writing notes (messages) and replying to those of others. Notes sent to the database can be sorted, for example, by date and person, and chat-rooms and e-mail are integrated in the system. The user may modify his or her personal portal to the VWS. Personal bookmarks are easily collected and stored in the database, and when the user re-enters the VWS, his or her private bookmarks and e-mail preferences will be loaded automatically. Discussion forums, public or private, can easily be created for each course. VWS is designed by the Media Center of the Helsinki City Department of Education.
2.2. Data collection

The following sources were used in data collection: we used material from VWS log files, and students’ notes from the VWS database.

2.3. Data analysis

To provide a comprehensive picture of our research questions, we used a combination of quantitative and qualitative methods in the data analysis.

2.3.1. Analyzing participation

We applied social network analysis to the VWS log files to analyze participation. From the log file information we computed the total number of notes posted to VWS, together with received and sent comments for each participant.

One can define at least two forms of participation in CSCL environments: writing notes and reading notes (‘lurking’). Writing notes means that a participant joins in a discussion and his or her notes are shared and can be discussed by all the participants. Reading notes means that participant only reads others notes without making any contribution to the computer-mediated discourse. In the present study, writing notes (“creating a note” and “commenting”) was chosen as an indicator of participation; the advantages of writing as a tool of thinking is recognized by several researchers. Writing has a crucial role in explication and articulation of one’s thinking (Bereiter & Scardamalia, 1987; Olson, 1994), and the externalization of ideas by writing, ‘making the thinking of students visible’, gives opportunity for students to reflect and share their ideas and expertise (Collins, Brown & Holum, 1991).

The definition of who is active and who is inactive in the class was made on the basis of percentile values; a participant was considered active if the participation rate (number of written notes) was in the upper quartile and inactive if it was in the lower quartile.

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 this could be a participant, as defined, composed of one, two or three students) and the strength of the relations; (for an example of a valued case-by-case matrix see Appendix B). In a case-by-case matrix the rows and the columns of the matrix represent the cases, for example, participants.

There are two important properties of relations. It is important to understand, firstly, whether the relation is directed or non-directed, and secondly, whether it is dichotomous (binary) or valued. In a directional relation the tie between a pair of actors is directed from one actor of the pair to another actor; for example, a participant sends note to another participant (see Appendix B). In a non-directional relation the tie between actors does not have a direction; the tie exists or it does not exist. A second important property of a relation is whether it is dichotomous or valued. Dichotomous relations are marked with only two values: 1, representing an existing relation; and 0 representing no existing relation. For example, one could rate whether
one participant sent a comment to another; the relation can take only two values, “send” (an existing relation) or “not send” (no existing relation). In valued relations the strength of each tie is recorded (Scott, 1991, pp. 47–50; Wasserman & Faust, 1994, pp. 148–150).

The case-by-case matrix was then analyzed with social network analysis. We examined interaction among participants with a density test. Density is a property of a whole network and describes the general level of linkage among the points in an interaction network. Participants were viewed as points, and links between nodes (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 (Scott 1991, pp. 72–73). Thus, the density of a network is at a maximum when all the points are connected to each other. The density value of a network varies between 0 and 1. While density describes the extent to which all participants, of a particular network are interconnected, centralization describes how tightly interaction within a network is organized around a particular focal point or points. Thus, density and centralization are complementary measures (Wasserman & Faust, 1994, pp. 101–102). The case-by-case matrix was dichotomized in density and centralization analyses.

To find the most central participants in the VWS mediated interaction, we calculated centrality values for each participant by using Freeman’s degree and betweenness measures. Freeman’s degree measures the network activity of participants—the proportion of all others with whom they communicate. The received comments were performed as indegrees, and sent comments as outdegrees. Freeman’s betweenness value gives another perspective to centrality. It shows how often a given participant is found in the shortest path between two other participants in the network of interaction (Wasserman & Faust, 1994).

In centrality measures, asymmetric data were used only in calculating degrees. In other cases we used symmetric data. Non-directed relations are always symmetric, that is, the top half of the matrix is identical to 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 (Scott, 1991; Wasserman & Faust, 1994). To illustrate this, consider the following: A sent three comments to B, and received two comments from A, which makes five altogether (see Appendix B).

Further, to analyze and visualize the participants’ interaction, we used multi-dimensional scaling (MDS). MDS allows one to translate a set of correlations (or other measures of association) among scaled variables into non-metric (ordinal) distances among points, and to locate each point relative to all others within Euclidean space in a way that is unaffected by the orientation of, or metric of, the dimension (Salomon, 1996). In other words, the basic idea behind MDS is that of using the concept of space and distance to map relational data. The social network analyses were executed with UCINET program (Borgatti, Everett & Freeman, 1999).
2.3.2. Analyzing the quality of discourse

On the basis of the previous studies (Guzdial & Turns, 2000; Hewitt & Tevlops, 1999; Lipponen, 2000), we chose two indicators for the quality of discourse. First, whether the discourse is sustained or not, and secondly, whether the discourse is focused on class learning topics or is off-topic (i.e. what kind of information circulates in VWS mediated discourse) (Guzdial & Turns, 2000; Lipponen, 2000).

In order to analyze whether the discourse is sustained, we identified the length of note threads (an example of a note thread is provided in Appendix A). Threads are composed of points, which are linked to one another through lines. All points in a thread—in this case, VWS notes representing points—are connected to each another through one or more lines. For example, a note created as a comment has a line to the note to which it refers (see Scott, 1991). Thus, if note A is posted, and B and C are both comments upon A, and note D is a comment upon C, the length of the thread is four. Threads are mutually exclusive; a note belongs to only one thread. We decided that the smallest acceptable thread for analysis would have just two notes.

To analyze whether the discourse is on-topic or off-topic, we applied qualitative content analysis (Chi, 1997; Hakkarainen, 1998; Lipponen, 2000). The coding schemes were not predetermined, but rather emerged through interaction with the data. Each comment was analyzed according to the following scheme (for details of classification, see Appendix C): (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 determine whether the students’ discourse represents reflective discourse (i.e. students request clarifications concerning fellow students’ questions and theories, see Bereiter, 1994; Lipponen, 2000; Van Zee, 2000) that might be mediating conditions for better collaboration and learning. Top-level notes (a note that starts a thread) and isolated notes (a note that does not receive any response) were categorized with the following scheme: (1) Is the note an isolated or a top-level note; (2), Is the focus of the note on-topic or off-topic; and (3) Does the note pose a research question, provide information, or something else. 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 comprise several ideas representing different categories of analysis, we decided the basic unit of analysis would be a note. This was because the notes usually consisted of a few sentences; it was very easy for the raters to find agreement concerning the class of the note. To validate the coding one rater coded the whole data, and a second rater separately coded 60 per cent of the data. The inter-rater coder agreement in all categories (focus of the comment, nature of the comment, function of the comment, type of the note, focus of the note, and function of the note) was over 89 per cent which was considered satisfactory.

Further, two participant cases are presented in order to give readers a more detailed picture of the possible relationship between participation and quality of discourse in VWS.
3. Findings

In this section, we describe how students participated in VWS work, and examine the quality of their discourse. Aspects presented are density and centralization of interaction, participation rates, centrality measures of interaction, and the quality of discourse.

3.1. Findings on participation

Density provides an indication of activity in the network—the extent to which participants are engaged in exchanging, for example, knowledge, opinions, support or critic. The denser the network is, the more participants have connections with each other. In a network of 12 participants (as in the present case), there are 66 \((12 \times 11 / 2)\) possible connections. The density of VWS mediated interaction was 0.39, which tells us that 39 per cent of class members collaborated through VWS during the project. The density was rather high. Studying a network of 28 participants, Palonen and Hakkarainen (2000) discovered that the density of this CSCL interaction was 0.28. However, it should be pointed out that in a small network the density value tends to be higher than in a network that has many participants; it is much easier to maintain many connections with a few participants than with very many participants. In a dense network, members are likely to mutually influence each other, and information that cycles in the network is distributed among many participants. Thus, a dense interaction can mediate peer interaction in a meaningful way. It can offer participants possibilities to pursue pedagogically valuable discourse; it may facilitate collective responsibility for advancing knowledge and distribution of expertise among participants.

We were also interested in whether the participants’ interaction, through VWS, had a centralized structure. The analysis indicated that the communication mediated by VWS was not very centralized, but was distributed among relatively many participants (in the case of outdegree the centralization was 40 per cent, and in the case of indegree it was 29 per cent). The outdegree centralization appears to be higher than the indegree, showing that some participants were more eager to make connections than others.

The total number of notes participants wrote was conceived as an indicator of participation. We can say that participation was broad based—all participants participated to some extent and produced, in all, 199 notes to the VWS database. As documented in Table 1, participants made between seven and 39 notes with an average of 16.58 (SD = 8.20) notes.

As Table 1 shows there were, however, substantial differences in the participants’ participation rates. Three participants, SoSaEl, EeSa and TiTe were the most active in the VWS work and wrote 39, 22 and 19 notes respectively. The most inactive participants were TaOs, JoMiOt, and Erkki (7, 12 and 9 notes respectively). SoSaEl, Kari, and TiTe also had a high number of isolated notes. In fact, over 60 per cent of TiTe’s notes, and over 47 per cent of Kari’s notes were isolates. It appears that they were active participants in VWS work, but were not very communicative. On
Table 1
Participants’ participation activity

<table>
<thead>
<tr>
<th>Participant</th>
<th>Gender</th>
<th>Total # of notes (sent comments, top-level and isolated notes) M=6.5, SD=0.5</th>
<th>Total # of top-level notes M=0.50, SD=0.6</th>
<th>Total # of isolated notes M=4.0, SD=0.4</th>
<th>Total # of sent comments (outdegree) M=0.00, SD=0.5</th>
<th>Total # of received comments (indegree) M=9.00, SD=5.5</th>
<th>Freeman’s Betweenness measure M=0.00, SD=0.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>%</td>
<td>Value</td>
<td>%</td>
<td>Value</td>
<td>%</td>
<td>Value</td>
<td>%</td>
<td>Value</td>
</tr>
<tr>
<td>25.00</td>
<td>12.25</td>
<td>25.00</td>
<td>2.00</td>
<td>25.00</td>
<td>1.25</td>
<td>25.00</td>
<td>5.00</td>
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<td>50.00</td>
<td>14.50</td>
<td>50.00</td>
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<td>50.00</td>
<td>6.50</td>
</tr>
<tr>
<td>75.00</td>
<td>18.75</td>
<td>75.00</td>
<td>4.75</td>
<td>75.00</td>
<td>5.75</td>
<td>75.00</td>
<td>10.50</td>
</tr>
</tbody>
</table>

RiAn m, m 14, 4, 5, 5, 7, 1.20
InJuKa f, f, f 15, 3, 1, 11, 11, 3.18
TaOs m, m 7, 1, 3, 3, 3, 0.43
JoMiOt m, m, m 12, 5, 1, 6, 9, 6.70
SoSaEl f, f, f 39, 4, 6, 29, 16, 9.47
SiNi f, f 13, 4, 2, 7, 10, 0.45
Kari m 18, 2, 8, 8, 5, 1.03
Sami m 17, 7, 5, 5, 9, 4.93
EeSa f, f 22, 5, 1, 16, 22, 0.63
TiTe f, m 19, 2, 12, 5, 2, 1.05
Erikki m 9, 2, 3, 4, 5, 1.33
Simo m 14, 3, 2, 9, 9, 6.53
Total 199, 42, 49, 108, 108
the other hand, the number of isolates might indicate that their notes were posted mainly to the whole class, not to some particular participant. The teacher did not write any notes. However, she did follow participants’ activities in VWS by reading notes.

To find the most central participants, we calculated centrality values for each participant by using Freeman’s degree and betweenness measures. It was not surprising to find differences in participants’ outdegree and indegree values (see Table 1). Participants’ outdegrees (sent comments) varied between three and 29 comments (M = 9.00, SD = 7.24), and indegrees (received comments) between two and 22 comments (M = 9.00, SD = 5.59). Every participant sent comments. Three participants, InJuKa, SoSaEl and EeSa had the highest outdegrees (11, 29 and 16 respectively), and four participants, RiAn, TaOs, Sami and Erkki had low outdegrees (5, 3, 5 and 4 respectively). High outdegree indicates that a participant actively creates connections to the other members of the network; in other words, is very communicative.

Every participant also received comments, which can be considered positive. Three participants, InJuKa, SoSaEl and EeSa had high indegrees (11, 16 and 22 respectively), and four participants TaOs, Kari, TiTe and Erkki had low indegrees (3, 5, 2 and 5 respectively). High indegree indicates that others are, for some reason, very often contacting this particular participant. This might indicate, for example, that the participant is a popular student in the class or that the nature of her or his notes and comments is in some way interesting or remarkable from the others’ point of view. On the contrary, low indegree indicates that a particular participant as a person, or his or her work, is not interesting from the others’ perspective, and participants who are associated with a high degree (indegree and outdegree summed) have the maximum connections with others and vice versa.

Betweenness measure—another perspective on centrality (in addition to degree)—showed that there were three participants, JoMiOt, SoSaEl, and Simo, who had the highest betweenness value. This indicates that they were in a central position in the network of VWS mediated interaction. Three participants, TaOs, Kari and EeSa, had a low betweenness value.

No participant had a high value in all the dimensions analyzed. But one of the participants, namely SoSaEl, had a high value on five dimensions—total number of notes created, outdegree, indegree, total degree (which is high because indegree and outdegree are high) and betweenness. We are justified, perhaps, in concluding that SoSaEl was the most visible and prolific participant in the VWS mediated communication during this project. By contrast, there was one participant, TaOs, who had a low value on all five of these dimensions, indicating an isolated position in VWS mediated interaction.

According to many researchers (Guzdial & Turns, 2000; Lipponen, 1999; Stahl, 1999), we (researchers and educators) should be concerned about the low level and uneven participation in CSCL environments; particularly, because the implicit promise of CSCL, and educational technology, in general, has been that they will democratize the participation of students. However, researchers often seem to ignore the fact that passive behaviour in public discourse and uneven distribution of participation are the problems not only in CSCL environments, but also in the traditional
classroom learning process and discussion (Cazden, 1988). However, there is evidence that CSCL may facilitate broad participation. Hsi (1997) researched CSCL discussions and found that students made more contributions in CSCL discussion than class discussion.

3.2. Findings on the quality of discourse

The total number of notes that were responses to some other note (i.e. comments) was 108, which is 54 per cent of all the notes \( (f = 199) \) posted to VWS (see Table 2). There were also notes that did not receive any response. The number of these isolated notes was 49, which is 25 per cent of the total number of notes in VWS (see Table 3). The most successful participants in starting discussions were JoMiOt, Sami and EeSa. They had 5, 7 and 5 top-level notes respectively.

Table 2
The quality of comments

<table>
<thead>
<tr>
<th>Focus of comments</th>
<th>Frequency</th>
<th>Per cent</th>
</tr>
</thead>
<tbody>
<tr>
<td>On-topic</td>
<td>63</td>
<td>58</td>
</tr>
<tr>
<td>Off-topic</td>
<td>45</td>
<td>42</td>
</tr>
<tr>
<td>Total</td>
<td>108</td>
<td>100</td>
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<table>
<thead>
<tr>
<th>Nature of comments</th>
<th>Frequency</th>
<th>Per cent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Positive feedback</td>
<td>13</td>
<td>12</td>
</tr>
<tr>
<td>Negative feedback</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Neutral</td>
<td>90</td>
<td>83</td>
</tr>
<tr>
<td>Total</td>
<td>108</td>
<td>100</td>
</tr>
</tbody>
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<table>
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<tr>
<th>Function of comments</th>
<th>Frequency</th>
<th>Per cent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Providing information</td>
<td>47</td>
<td>44</td>
</tr>
<tr>
<td>Asking clarification</td>
<td>16</td>
<td>14</td>
</tr>
<tr>
<td>Other</td>
<td>45</td>
<td>42</td>
</tr>
<tr>
<td>Total</td>
<td>108</td>
<td>100</td>
</tr>
</tbody>
</table>

Table 3
The quality of isolated and top-level notes

<table>
<thead>
<tr>
<th>Focus of isolated and top-level notes</th>
<th>Frequency</th>
<th>Per cent</th>
</tr>
</thead>
<tbody>
<tr>
<td>On-topic</td>
<td>63</td>
<td>69</td>
</tr>
<tr>
<td>Off-topic</td>
<td>28</td>
<td>31</td>
</tr>
<tr>
<td>Total</td>
<td>91</td>
<td>100</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Function of isolated and top-level notes</th>
<th>Frequency</th>
<th>Per cent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Research questions</td>
<td>22</td>
<td>24</td>
</tr>
<tr>
<td>Providing information</td>
<td>41</td>
<td>45</td>
</tr>
<tr>
<td>Something else</td>
<td>28</td>
<td>31</td>
</tr>
<tr>
<td>Total</td>
<td>91</td>
<td>100</td>
</tr>
</tbody>
</table>
Overall, the VWS discussion was composed of 42 note threads, which ranged from two to 11 notes in length. The mean size of a thread was 3.57 (SD = 2.39). The mean length of threads shows that in an average note thread, there was a starting note (top-level note) and two to three responses. The high number of short threads within a project suggests that the discussions are not sustained, but that they proceeded along diverging lines (Hewitt & Tevlops, 1999). According to Hewitt and Tevlops, a discussion thread of substantial length is essential for continuous discourse. The probability of a thread’s growth is related to the thread’s size and, to some degree, to the age of its notes too. The length of note threads seemed to have an impact on the quality of the discourse. The nature of students’ comments is documented in Table 2.

Of the comments that participants sent to each other, 58 per cent were on-topic, and 42 per cent off-topic. But if we consider all the notes that participants posted to the VWS database, the proportion of on-topic notes was 63 per cent and off-topic notes was 37 per cent (see Table 4). An interesting question is to examine the optimal proportion of off-topic and on-topic communication for effective learning and collaboration.

Of those comments that were on-topic, 75 per cent were provided information and explanations, while 25 per cent sought clarification. This demonstrates that while commenting on the topic participants mainly appeared to answer each others questions or to provide more information for fellow students’ inquiry. Answering others’ questions or commenting on others notes by providing new information and explanations, it is evidently an important part of effective communication. This type of pattern, however, is not enough. In a reflective discourse students should not only be seeking understanding by offering answers and explanations, but also requesting clarification fellow students’ questions and theories (Bereiter, 1994; Lipponen, 2000; Van Zee, 2000). Thus, in order to represent genuine reflective discourse, participants should have been asking for more clarification in the course of VWS mediated knowledge construction. Moreover, in a reflective discourse the length of discourse threads should be longer; there is little hope for reflection if the average depth of discourse is only a few steps. The off-topic comments were mainly focused on social issues such as greetings or telling-offs, representing discourse that might be called social-oriented discourse (Lipponen, 2000).

There is one more feature in the quality of participants’ VWS discourse that merits discussion. There were no genuine heated discussions with participants taking sides of issues or negotiating meaning—the high proportion of neutral comments was strik-

<table>
<thead>
<tr>
<th>Focus of isolated and top-level notes</th>
<th>Frequency</th>
<th>Per cent</th>
</tr>
</thead>
<tbody>
<tr>
<td>On-topic</td>
<td>126</td>
<td>63</td>
</tr>
<tr>
<td>Off-topic</td>
<td>73</td>
<td>37</td>
</tr>
<tr>
<td>Total</td>
<td>199</td>
<td>100</td>
</tr>
</tbody>
</table>
ing (83 per cent) (see also Lipponen et al., in press). How should we account for this neutrality of communication? Was it shyness, caution, or merely following the teacher’s lead or her instructions? In only a very small number of comments did participants really express positive or negative feedback. What was encouraging is that the proportion of negative comments (5 per cent) was very small; even smaller than the proportion of positive comments (12 per cent). This issue—the neutral culture of communication and the reasons for that—is a topic for which we do not have an answer. It needs to be studied in future investigations.

We also wanted to know who is communicating with whom, and whether the quality of notes in any sense explain a participant’s visible or isolated position in VWS-mediated interaction. In the following, we explore more closely two cases, namely those of SoSaEl, who was the most visible participant in the VWS-mediated communication, and TaOs, who appeared to be in an isolated position in the network of interactions.

Fig. 1 represents the MDS concerning the pattern of participants’ interaction. The interaction was used as a measure of similarities; the more messages the participants sent or received from certain students, the closer they are situated in the three-dimensional MDS map. The stress value, a measure of the quality of the MDS map, was 0.018, and was at an excellent level (<0.025) (Borgatti et al., 1999). As seen in Fig. 1 SoSaEl, InJuKa and EeSa are close to each other in the MDS map. In other words, they were communicating intensively with each other.

Interaction between these three participants was very intensive. If we sum up their received and sent comments, there were 16 comments between EeSa and SoSaEl,
eight comments between InJuKa and EeSa, and six comments between SoSaEl and InJuKa. The interesting question is then why did these particular students have that intensive interaction? One obvious explanation could be that these nine students are girls; according to the teacher, many of them are also good friends, and thus might share the same focus of interest. Interestingly, however, data from the same class and from a project where all the students worked individually in a CSILE environment, show that students’ communication did spread equally among gender groups; the communication did not reflect gender-based cliques, but girls commented actively on boys’ notes and vice versa (Lipponen et al., in press). Thus, on the basis of these data, the gender effect does not appear robust, and the issue needs to be studied in the future.

SoSaEl created 39 notes; 49 per cent of these notes were on-topic and 51 per cent off-topic. This participant started four discussions and posted six notes to the VWS database that did not receive any response. SoSaEl had the highest indegree and was also active in creating connections with other participants, being in contact with all other participants, but not with TaOs. SoSaEl sent comments to nine participants (the highest number of contacts) and received comments from seven participants (only Simo received comments from a higher number of participants). Why then were others interested in SoSaEl’s notes? SoSaEl’s high indegree might be, at least partly, a result of the high number of sent comments. We might expect that if one is communicative and sends many comments, as SoSaEl did, one also has a chance of receiving many replies. Since over half of the notes SoSaEl created were off-topic, it seems plausible to conclude that others were not interested in SoSaEl’s notes mainly for the sake of the information they contained. Further, the proportion of SoSaEl’s positive comments was not very high, and the notes were not provocative in the negative sense.

One explanation for others’ interest in SoSaEl’s work would be that the students that comprised participant SoSaEl are popular and active students in the class, and for that reason they were also popular in the VWS-mediated discussion. On the other hand, the genre of SoSaEl’s communication style could be perhaps characterized as conversational (responses were spontaneous and informal, such as, ‘Hi, it doesn’t bother us anymore’), which in some studies has been found to produce greater participation and more complex student interaction (Ahern, Peck, & Laycock, 1992).

Our second case was TaOs, who appeared to be in an isolated position in the network of VWS-mediated interactions. The first thing that drew attention is that TaOs created only seven notes during the project, and perhaps as a consequence, also received only three comments. We do not know why there were so few notes, and the following are some questions for which we do not have answers: Did TaOs students find that participating in the CSCL environment would be a good way to learn? Did they have a genuine, experienced desire to participate in VWS work or did these students work more outside of VWS? We note that the quality of notes TaOs posted to VWS was extremely high, and all were focused on-topic (e.g. ‘We measured the width of our pupils, and then again after we had looked into a light; the pupils shrunk one millimeter’). If the criteria for other participants’ interest had been the quality of notes then TaOs would probably have received more response.
Both cases—SoSaEl and TaOs—showed that participants’ position or visibility in the VWS-mediated discourse is only partly based on the subject-related quality of their notes and their own activity; other factors that might have had an impact are the social characteristics of the notes, participants’ friendships and popularity in the class. However, there is yet no empirical research on these issues in the context of CSCL. Furthermore, these two cases showed in more detail that there are differences, not only in the participants’ participation activity, but also in the quality of participation in VWS-mediated discourse.

4. Conclusions

The purpose of the present study was to analyze the patterns of participation and quality of students’ discourse in online discussion mediated by the VWS. This issue takes on great importance in studies concerning CSCL. If educators, researchers and software developers are going to implement CSCL on a large scale, they definitely need more information on patterns of working on CSCL in realistic settings; in ordinary school contexts where the teachers and the students work without extensive external support from research staff.

By combining social network analysis and qualitative content analysis, the present study gives insights into new methodological possibilities. This combination of methods appears to be appropriate for studying the participation and interaction processes that take place in CSCL environments, and in electronic discussion forums, in general. Social network analysis brings out interesting interaction and participation structures, which then can be further analyzed with qualitative content analysis.

Our analysis did not deal with whether the active or inactive participation and quality of discourse were related to learning outcomes. Thus, our data and analysis are to be considered more as effects with CSCL—the effects of CSCL; what participants have perhaps learned, goes beyond the scope of the present study. This study gives information about participation and discourse patterns that may be mediating conditions for better collaboration and learning. However, student interviews would have been helpful to validate our interpretations of students’ participation and discourse. Such interviews are being performed in ongoing studies.

The present study showed that the interaction between participants was rather dense. This may be a valuable feature of interaction, because in a dense network many participants have connections with each other, and members are likely to mutually influence each other; knowledge (or ideas, advice, etc.) is distributed among many participants. On the other hand, in a very dense network, however, widespread exchange of messages can lead to information overload. Thus, we have not yet identified the optimal or “normal” density of networks in collaborative environments for learning (Haythornthwaite, 1999; Nurmela et al., 1999).

A positive result was that participation was broad based—all participants participated to some extent. As reported by Guzdial and Turns (2000), the participation ratio (i.e. the ratio of the authors in the CSCL to the number of students in the class) in courses using CSCL seldom appears to be 100 per cent. We do not know, however,
how students distributed the work within participant groups; whether students shared
the cognitive responsibilities equally, or whether there were, for example some off-
loading of cognitive responsibilities to other individuals.

Despite the rather broad participation, participants engaged in VWS work with
very different levels of activity, some being very active and some inactive. These
results are consistent with results of previous studies concerning students’ partici-
pation rates, although the latter studies have mainly concentrated on individual stu-
dents at a higher educational level (Guzdial & Turns, 2000; Hewitt & Tevlops, 1999;
Muukkonen et al., 1999). These studies indicate that students do not participate very
intensively in CSCL environments. As a consequence, perhaps, the discussion thre-
ads in CSCL forums are quite short (Guzdial, 1997; Guzdial & Turns, 2000; Hew-
itt & Tevlops, 1999). The results of the present study parallel this finding. The high
number of short discussion threads within a project indicates that the communication
is not sustained. Altogether, these results appear to indicate that regardless of the
educational level there is often a lack of sustained and connected discussion in
CSCL environments.

Why then are threads only three to four notes in length? A threaded discussion
is time- and effort-consuming to follow (Muukkonen et al., 1999; Stahl, 1999). While
working with VWS, students might have faced substantial knowledge management
problems. A large number of messages in the VWS database can make it difficult
to follow the discussion, and get an overview about issues being discussed. It is
possible that this hinders the making of contributions. Further, making contributions,
staying on-topic and building on others ideas is not easy. We should also remember
that, in many cases, students of lower grade levels are not necessarily fluent writers
and readers, and might have difficulties in participating in forums that require them
to express their thoughts as text (Lipponen, 1999, 2000; Roschelle & Pea, 1999).
This might restrict the activity and quality of their participation.

Here, we have mainly focused on structural threads (i.e. how the system organizes
discussions). However, looking just at structural threads gives a limited picture of
CSCL discussions. In the future, investigators should also look at “conceptual thre-
ads”, that is, notes or note threads that are semantically or conceptually connected
to each other. An example of a conceptual thread would be all the notes posted to
solve some particular research question. This approach might be fruitful when
assessing whether some mediating conditions for learning have been met or what
students have really learned.

The study further revealed that participants had quite different positions in the
VWS-mediated interaction, some of them having central position others with more
isolated. This is clearly an important information for the teacher (and should also
be represented to the users); something needs to be done in order to involve the
isolated participants more actively in the network of interactions mediated by VWS.
Students’ positions in a network of CSCL interaction and its impact in learning is
a very seldom studied topic. It needs to be investigated in forthcoming studies.

How then can we facilitate participation in CSCL environments? One very interest-
ing solution would be to represent the interaction to the users online for example,
by using the information social network analysis produces. It would make a learner
aware of the key centres of activities, who is working with whom; it would help learners to participate in advancing collective knowledge. Other factors that might increase active and meaningful participation in CSCL environments include promoting alternative views for students to discuss, anchoring discussions to students’ personal experiences, giving an 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 (Hoadley & Linn, 2000; Hsi, 1997). However, researchers still lack solid empirical evidence as to whether the suggested support for participation would override social factors such as friendship or a participant’s popularity in the class. These two factors may, according to the present study, at least partly, determine participants’ position in CSCL interaction.

The results of this study support some previous findings (Guzdial & Turns, 2000; Hara et al., 2000) that discussions in CSCL environments tend to focus on class learning topics. This means that some learning and new understanding might also have occurred. On the other hand, the role of social interchange was also pronounced. Although social exchange is not probably very valuable for learning academic subjects, it might serve some important functions, such as activating participation in discourse, increasing motivation, and building a community.

Perhaps, we are justified in concluding, on the basis of the present evidence, that computer-supported collaborative environments at least give possibilities for active participation and on-topic and reflective discussions. Whether these possibilities are ever realized might depend on factors such as context, educators’ practice and students’ motives and interests.

Appendix A. An example of a note thread

21.03.2000 11.12.03 Problem Eyesight (JoMiOt)
“Can eyesight be cheated? if it can be cheated, then how?”
21.03.2000 11.24.37 Problem (Kari)
“Of course eyesight can be fooled. It can be fooled with conjuring tricks.”
21.03.2000 11.19.17 Problem Answer (InJuKa)
“Sure eyesight can be tricked. For instance, in the science centre Heureka there exists a cube that actually is composed of four slabs.”
21.03.2000 11.15.12 Problem Answer (TaOs)
“Eyesight can be cheated; we do not know how the vision works, however.”
28.03.2000 10.51.12 Problem Cheating the eyesight (JoMiOt)
“You are right. Eyesight can easily be cheated. Human vision is so-called stereo vision. This means that if one eye sees an object from one angle, and the other eye from some other angle, then the object is seen as one three-dimensional object. One way to cheat eyesight is to give a different picture for both eyes.”
Appendix B. 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.

<table>
<thead>
<tr>
<th>Participant</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>–</td>
<td>3</td>
<td>2</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>B</td>
<td>2</td>
<td>–</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>C</td>
<td>3</td>
<td>2</td>
<td>–</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>D</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>–</td>
<td>1</td>
</tr>
<tr>
<td>E</td>
<td>4</td>
<td>3</td>
<td>4</td>
<td>2</td>
<td>–</td>
</tr>
</tbody>
</table>

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

The excerpts in the brackets are from current VWS data.

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. “Of course eyesight can be fooled. It can be fooled with conjuring tricks”).

Off-topic. The focus of the comment is any other than the 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 is a really good experiment design’).

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

Neutral. The comment cannot be classified as either of the two previous categories (e.g. “Very loud noise is dangerous for hearing”).

Function of the comment

Providing information. The comment provides information concerning the class-learning topic or practices of inquiry (e.g. “Very loud noise is dangerous for hearing”).

Asking for clarification. The comment asks for clarification concerning the class-learning topic or practices of inquiry (e.g. “How did you design your experiment?”).
Other. The comment cannot be classified as either of the two previous categories (e.g. “You are stupid”).

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. “Is it possible to hear ultrasounds?”).

Off-topic. The focus of the note is any other than the class-learning topic or practices of inquiry (e.g. “Hi everybody”).

Function of the note

Asking research question. (e.g. “Can eyesight be cheated?”).

Providing information. (e.g. “We think that sight is our most important sense”).

Something else. (e.g. “Hi everybody”).

References


