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Metacognition in joint discussions: an analysis of the patterns of interaction and the metacognitive content of the networked discussions in mathematics

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Abstract The aim of this study was to examine metacognition in computer-supported collaborative problem solving. The subjects of the study were 13-year-old Finnish secondary school students ($N = 16$). The Knowledge Forum learning environment was used to support student pairs' problem-solving task involving polygons in a geometry course. The data consist of the student pairs' posted computer notes ($n = 95$). To examine metacognition in a social context in the networked discussions, the features and patterns of networked interaction, the metacognitive content of the computer notes and their relations were examined. To examine the features of networked interaction, the social network analysis measures were used. The patterns of networked interaction were displayed with the multidimensional scaling technique. In the analysis, metacognitive contents of the computer notes were categorized as *metacognitive knowledge, metacognitive skills*, and *not metacognitive*. Further, with the correspondence analysis, we examined how the student pairs' metacognitive activity was distributed. The results of the study revealed that the metacognitive activity varied among participants, although some aspects of metacognition such as planning were never encountered. It was found that there is a relation between metacognitive activity and the features of interaction. The student pairs who monitored and evaluated the ongoing discussions had a strategically optimal position in the communication network.

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Introduction

In many schools today, students are confronted with networked learning environments that aim to support social interaction and knowledge construction. It is expected that the students compare their thinking with their peers', which requires both the knowledge and regulation of their own thinking and cognitive processes. That is to say, that in the collaborative learning situation, the students should be closely involved in metacognitive activity. Even though computer-supported collaborative learning, CSCL, engages students in collaborative learning activities (Lipponen, 2002; Järvelä, Veermans & Leinonen, 2006), the role of metacognition in social interaction is not clear. Thus, the aim of this study is to examine metacognition in a collaborative framework supported by networked technology in a secondary school classroom.

The research on metacognition in learning has its roots in examining an individual's knowledge of cognition and regulation of cognitive processes (Flavell, 1979; Brown, 1987). Furthermore, the role of metacognition in an individual's problem solving has been emphasized for example in mathematics learning (e.g. Schoenfeld, 1987, 1992; Garofalo & Lester, 1985; Davidson & Sternberg, 1998). Currently, it has been shown that instructional methods like IMPROVE utilized in mathematics learning (e.g. Mevarech & Fridkin, 2006) and peer-questioning (e.g. King, 1990; in online discussions Choi, Land & Turgeon, 2005) can be used to facilitate metacognition. In these studies, metacognition is seen as an individual process which can be influenced by a teacher or a peer. Peers have a central role in the recent research on metacognition which has suggested that metacognition appears to be a part of the collaborative learning situation (Goos, Gailbraith & Renshaw, 2000; Vauras, Iiskala, Kajamies, Kinnunen & Lehtinen, 2003; Iiskala, Vauras & Lehtinen, 2004) where metacognitive regulation is considered also as a group level activity rather than only as an individual's performance.

The foundations of viewing metacognition as a part of the collaborative learning situation could be grounded in the theoretical idea of socially shared cognition (Resnick, Levine & Teasley, 1993; Levine, Resnick & Higgins, 1993) in which thinking and cognition are seen as social practice. Rather than seeking to understand cognitive and social processes in isolation, it is argued that thinking can be regarded as a socio-cognitive activity in which thinking and cognition can be shared through the learning environment among participants (Resnick, Levine & Teasley, 1993). In other words, students learn in social interaction with peers. They are dependent on what their peers know (Brown, 1994), and it is not always clear whether learning is an individual's achievement or the result of a group's activity (Artzt & Armour-Thomas, 1992, 164). In the collaborative learning situation, it is expected that learning occurs when the students work together and make their thinking visible by asking questions, providing explanations, and discussing their differing viewpoints (Dillenbourg & Traum, 2006). The mechanisms of learning by which students learn while working collaboratively are explained by using Piaget's concepts of socio-cognitive conflict and coordination of perspectives (Piaget, 1954, 1978), and Vygotsky's (1978) construct of the zone of proximal development (ZPD).

Shared cognition and metacognition in networked interaction

A pedagogical model of computer-supported collaborative learning (Koschmann, Hall & Miyake, 2002) has been used to organize a learning situation in which the students are encouraged to make their thinking visible by externalizing their thinking and contributing their written messages to the learning environment's database to ask questions and propose counter-arguments and comments (Brown et al., 1996; Scardamalia & Bereiter, 1996a, b; Cohen & Scardamalia, 1998; Lehtinen 2003). The messages saved in the database are continuously available to the students, and the structure of the discussion is visualized. This visualized thread enables the students to step back and consider their own and their peers' cognitive processes as objects of thought and reflection, which is also a feature of metacognitive knowledge (Flavell, 1979). The student can then decide whether to take part actively in the discussion by asking questions, seeking help and providing explanations (Newman 1994; Aleven, McLaren, Roll & Koedinger, 2004), or passively by reading computer notes in a database and taking advantage of their peers' ideas.

Active participation in networked learning requires a different kind of monitoring and control of cognitive actions compared to passive participation. For example, the construction of explanations (Ploetzer, Dillenbourg, Preier & Traum, 1999), providing and seeking help (Newman, 1994) encourage the students to become aware of their thinking. By constructing explanations, the students become aware of the missing knowledge and what they do not understand (Webb, 1989). The students can reflect on these cognitive processes and discuss what they do or do not know with others. For example, being able to send a message to the database concerning what information is missing identifies the student as having metacognitive knowledge of the problem to be solved (cf. Brown, Bransford, Ferrara & Campione, 1983). In networked discussion, it is also essential that the students try to formulate their ideas so precisely that the content of the computer note is understandable to the other participants. Thus, the students are able to use their inter-individual metacognitive knowledge (Flavell, 1979; Brown, 1987) of what their peers know and understand (Blumenfeld, Marx, Soloway & Krajick, 1996) when planning to contribute a message to the database.

The recent studies on metacognition in peer interaction have been viewed in the context of collaborative learning in mathematics. According to these studies it is possible to create overlapping zones of proximal development, and the metacognitive activity is mediated among participants (Goos et al., 2002). There are also findings that show metacognition to be a socially shared phenomenon in collaborative learning (Iiskala, et al., 2004). Moreover, Jermann's (2004) study shows that while students regulate their own activity in collaborative learning, they are also able to monitor and control how their peers are working in the group. Expanding these ideas, it is hypothesized that in the networked collaborative learning environment and CSCL pedagogical model there are metacognitive processes which can also be stimulated by peers. In addition, especially when studying metacognition as a shared process, it is essential to apply methods that aim to combine social and individual level analysis.

Aim

The aim of this study is to examine the social aspects of metacognition in secondary school students' networked interaction in mathematical problem solving in geometry. More specifically we studied in the collaborative framework:

- What kinds of participant pairs' metacognitive processes are present in joint problem solving in networked interaction?
- How do the metacognitive processes vary among participants?
- Is there a relation between the degree of participation and the different metacognitive processes in joint problem solving?

Materials and methods

Participants

The participants in the study were 13-year-old Finnish secondary school students (N = 16). Their mathematics teacher described them as skilled learners in the domain (the average mathematics grade in the student group was 9 on a scale 4–10), and she said that the students were skilled at making their thinking visible and at discussing mathematical problem-solving strategies and concepts. The participants shared a common history at school so it could be assumed that they had an equal knowledge of mathematics. They had used the Knowledge Forum (KF) learning environment (Scardamalia & Bereiter, 1996a, b) in a literacy course so were familiar with the learning environment's technical features, and they had previous experience of networked discussions. The students worked with the KF during mathematics lessons in school. Because of the limited number of computers in the school's computer classroom, the students worked in pairs formed by the teacher. Although the computer notes were written in pairs, each student had a user account and password to log into the Knowledge Forum.

Procedure

The geometry course lasted for 16 lessons, each of which lasted 75 min. The time frame within which the course occurred was from December to the beginning of February. The KF was used in three lessons during one week. The aim of the Geometry project was to encourage the students to make their thinking visible, and to use the KF learning environment to support the student pairs' problem-solving task concerning polygons. During the three lessons, the student pairs posted 95 computer notes.

At the beginning of the Geometry project, the user accounts and passwords were given to the students. They were given a short demonstration of the kind of discussion which is appreciated in geometry while working with the KF. The reasons for applying networked discussions were also presented to the students. For example, learning to formulate explanations and to evaluate other students' solutions and problem-solving processes were discussed. The teacher explained the procedure of a problem-solving task concerning the polygons. Instructions were given for the problem-solving task as follows, "Write a computer note including definition, properties, finding the area and perimeter, the sum of the measures of the angles, and then invent a problem concerning the polygon, and solve your problem". Each student pair selected the topic of the task randomly. The topics were a trapezium, a square, an obtuse triangle, a right triangle, an acute triangle, an equilateral triangle, a rectangle and a parallelogram. In the networked discussions, the students were asked to read each other's notes about a problem-solving task and make comments by proposing improvements, asking for further clarification, and then complete their own notes on the basis of the received comments. Thus, there were two different kinds of computer notes in the database; the notes involving the problem-solving task which were carefully thought out beforehand, and the notes that the student pairs wrote in situ.

Data collection

The data consist of the students' posted computer notes, $n = 95$. The computer notes include the teacher's instructional note and student pairs' problem-solving notes, as well as the following discussion. The students formed eight pairs and in the data analysis the student pairs were encoded as b2b3 indicating a pair of boys formed by boy 2 and boy 3. Respectively, the denotation g1g2 means a pair of girls. The denotations are used to preserve the anonymity of the participants and for the sake of consistency in the different data analyses. The teacher also participated in the networked discussion. Below, the expression "participants" denotes all the student pairs and the teacher.

Data analysis

Multidimensional Scaling, MDS

The methodological solution used to examine metacognition in the collaborative framework in joint problem solving consists of four different analyses. First, the multidimensional scaling technique, MDS (Scott, 1991), was used to graphically display the patterns of interaction in joint discussion (Nurmela, Lehtinen & Palonen, 1999). Although the computer-supported learning environment was provided for the student pairs to support collaboration and the sharing of their ideas, it is not certain that they do negotiate and construct knowledge with their peers. It may also be the case that the learning environment's database consists only of the student pairs' own postings without any replies. Therefore, the patterns of interaction are examined first in order to clarify with whom the students worked and whether they had reciprocal relationships, defined as student pairs making comments and replying to each other's computer notes. Thus, the analysis was based on active participation not on passive participation. The basic idea behind multidimensional scaling (MDS) is that of using the concepts of space and distance to map relational data. In this study, the relational data consists of the posted computer notes that is the send and received messages among participants. The higher number of the computer notes means the smaller distance in the map. Multidimensional scaling is an attempt to convert graphic measures into metric measures (Wasserman and Faust, 1994; Scott, 1991). The goodness of each multidimensional scaling map can be measured by a value of stress, where the greater value means the poorer model. The value is, however, dependent on the data: the number of actors and the scales of measures. Analyses were performed on a symmetric matrix. The symmetry was produced by summing up the received and sent messages. In this way the both halves of matrix became similar. In the analysis, the ties between two student pairs or between a student pair and the teacher are seen as reciprocal if both parties have sent and received at least one message to and from each other.

Qualitative content analysis of the computer notes

Although the multidimensional scaling technique provides information about how the students interacted with each other, it does not tell us what the metacognitive content of the computer notes was. In order to get a deeper understanding of what kind of metacognitive processes there were in joint problem solving, the second phase of the data analysis, qualitative content analysis (Chi, 1997) of the student pairs' computer notes was performed. The unit of analysis was a computer note categorized either as *metacognitive knowledge* including a person, task and strategy variables (Flavell, 1979; Brown, 1987), or as *metacognitive skills* including planning, monitoring and evaluating (Flavell, 1979; Brown, 1987; Schraw & Dennison, 1994), or as *not metacognitive*. The computer notes were categorized according to the main content of the message in relation to an ongoing discussion topic. In the examples, the students' names have been changed and, in parenthesis, the denotations of the student pairs are presented. The categories including the data-driven examples were as follow:

1) The *metacognitive knowledge* category sums up all the student pair's posted computer notes that consist of the features of person, task and strategy variables.

   1a) The *person variable* identifies knowledge about self as a problem solver.
   1b) The *task variable* concerns knowledge of the task and how it influences cognition.

      Example 1. Peter and Jake's [b8b9] Note 308.
      Title: It is supposed so that more than 180 degrees
      "It is supposed that more than 180, so then it [the mark of an angle] is outside, otherwise inside."

   1c) The s*trategy variable* involves knowledge of when and how to use different strategies.

      Example 2. Teacher's Note 315.
      Title: Impossible
      "You say that a triangle has sides with lengths 5 cm, 10 cm and 15 cm. That is not possible. You will notice it if you try to draw the triangle."

2) The *metacognitive skills* category sums up all the student pair's posted computer notes that consist of the features of planning, monitoring or evaluating.

   2a) *Planning* identifies what the student pair is going to do next, or how the other student pairs' sent messages affect the future performance.

   2b) *Monitoring* concerns assessment of one's learning and strategy use.

   Example 3. Lisa and Rosa's [g1g2] Note 283.
   Title: there is something strange in your picture.
   "as a matter of fact, that red circle marking the angle of 120 degrees should be inside the figure. Try to think how many degrees the angle you've marked would be? It might be much more than 120.."

   Example 4. Sarah and Ralph's [g5b1] Note 335.
   Title: should the t:2, a
   "so when calculating the area should it be divided by 2??"

   2c) *Evaluating* involves messages that showed analysis of performance and a strategy effectiveness in the problem-solving and the joint discussion about it.

   Example 5. Cindy and Carol's [g6g7] Note 333.
   Title: We changed the example
   "We changed the example, now it should be correct. Could someone check it?"

   Example 6. Peter and Jake's [b8b9] Note 342.
   Title: maybe......but...
   "but it changes automatically e.g. 181 degrees.. think!"

3) *Not metacognitive notes* were notes that did not show metacognitive activity.

   Example 7. Bob and Michael's [b4b5] Note 281.
   Title: A quite nice [note]
   "This note is ok. There could also be a picture too".

Some of the examples above have been taken out of the original discussions. For instance, examples 1 and 6 are parts of a networked discussion in which the student pairs are intensively negotiating how to mark an angle of a polygon (see the discussions in Hurme & Järvelä, 2005). Example 7 shows that the students Bob and Michael are telling the other student pair that their note is a good one without saying why. In order to be classified as metacognitive the computer note should be referring to the ongoing discussion or should provide reasons for arguments.

Further, we also examined whether the content of the student pair's computer notes indicated regulation of their understanding (*supporting pair's own thinking)*, or whether the focus of the computer note was to guide and support the other pairs' problem solving (*supporting other pairs' thinking)*. These categories can include computer notes categorized as *metacognitive knowledge* and *metacognitive skills*. For instance, a student pair can bring their metacognitive knowledge into discussions and thus provide vital information to help their peers to proceed in problem solving. If the computer note did not indicate metacognition it was encoded as non-focused.

4) *The focus of metacognitive messages* consists of the categories of *supporting pair's own thinking, supporting other pairs' thinking* and *non-focused*.

4a) *Supporting pair's own thinking* consists of computer notes that concerned the monitoring or regulation of a student pair's own thinking, or an expression of what kind of information the student pair is going to need.

Example 8. Peter and Jake's [b8b9] Note 328.
Title: I have always had an understanding…
"but what Sarah were asking"

4b) *Supporting other pairs' thinking* is about mediating metacognitive knowledge, or an attempt to guide and support the other participants' activities in networked discussions.

Example 9. Tina and Helen's [g3g4] Note 274.
Title: So this is not the real note '
"See, it was the question we were looking for the answer because we were note sure whether the sum of angles [in a triangle] is 180 degrees".

4c) The *non-focused* category was used when the content of the computer note did not refer to metacognition, and the focus of the computer note was not on reflecting the student pair's own thinking or to guide and support their peers in problem solving.

Example 10. Cindy and Carol's [g6g7] Note 296.
Title: An example in right place!
"Now in the note of the acute triangle an example is added. So if you have anything to ask: ASK! "

As mentioned above, there were two different kinds of computer notes in the database; the notes involving the problem-solving task which were carefully thought out beforehand, and the notes that the student pairs wrote in situ. Although, all the posted computer notes can be considered as a result of a student pair's activity, there are no data on metacognitive and regulatory activity within a student pair. Thus, the metacognitive contents of the student pairs' computer notes can be analysed like an individual's contribution to the database. Further, the student pairs' computer notes involving the problem-solving task were encoded as not metacognitive.

Correspondence analysis

In the third data analysis, the aim was to explore how the metacognitive processes varied among participants by using a correspondence analysis (Greenacre, 1984; Greenacre & Blasius, 1994). The correspondence analysis describes the relationships between two nominal variables, the participants and the metacognitive content of the computer notes, in a low-dimensional space. It also describes, simultaneously, the relationships between the categories for each variable. Thus, it can be said that the correspondence analysis is an explanatory data analysis method, where there is no statistical hypothesis to be tested (Greenacre, 1984). To examine how the metacognitive processes varied among participants, calculation of row profiles and the goodness-of-fit test by chi-square statistics were performed, with a p-value <0.05 which is a good level. The row profiles are the same as conditional distribution in contingency tables although the term is not used in correspondence analysis. In addition, the mass values for the metacognitive categories were calculated to get an understanding of how the different kinds of metacognitive activities, *metacognitive knowledge, metacognitive skills and not metacognition*, were weighted in the data.

Another feature of correspondence analysis is that it displays contingency table data as a graphical presentation, a correspondence map. For the correspondence map, the Chi-square distances, symmetrical normalization, and the standardization, by removing row and column means, were used. These alternatives are used for standard correspondence analysis in which the goal is to examine the differences or similarities between the categories of two variables (Greenacre, 1984), like in this study, how the metacognitive processes varied among participants. The correspondence analysis was performed with SPSS 12.0.

Social network analysis and the features of interaction

In the fourth data analysis, the features of interaction were described with the following measures of the social network analysis (Scott,1991; Wasserman & Faust, 1994): received notes (in-degree value), sent notes (out-degree value), number of dialogue partner pairs (neighbourhood size), the reciprocity of the communication, and the betweenness value, which indicates the position of the student pair in the communication network. A detailed description of the measures is given below.

1) *Received notes* show the number of computer notes the other student pairs had sent to the student pair.
2) *Sent notes* are the number of computer notes the student pair had sent to the other student pairs.
3) *Size* concerns the number of dialogue partner pairs, illustrating how many others the student pair was connected to.
4) *Reciprocity* of the interaction shows the number of student pair connections that were reciprocal, in percentages. Reciprocity is defined as an event in which one student pair or a teacher is sending a message to and receiving a reply from another participant. The degree of reciprocity for each participant is the number of mutual relationships divided by the number of all relationships multiplied by a hundred.
5) *Betweenness* shows how often a network actor's position is strategically important in the communication structure, i.e. how central the network position is. Interactions between two nonadjacent actors (i.e. actors who are not directly interacting) depend on the other actors who lie in the paths between the two. A student pair has a high betweenness value if it lies between two actors in the network who are not directly connected to each other, given that the shortest distance between two actors in the network is used to calculate the betweenness (Wasserman & Faust, 1994).

These measures were chosen to obtain a more detailed picture of the features of interaction in networked learning. The relational structures can be used to describe social phenomena where interactions between participants are observed. To examine the relationship in between the active participation and metacognition, the correlations between metacognitive processes and the features of interactions were calculated.

Results

Patterns of interaction

In terms of what kinds of patterns of interaction there were, the results show that the student pairs formed a social network (see Figure 1). It can be seen that there were no isolated participants because each pair had at least one reciprocal connection to another student pair or to the teacher. The multidimensional scaling map presented in Figure 1 can be regarded as a socio-gram where the distances have been calculated on the basis of the interaction. The stress value in the figure (see Figure 1) is 0.08, which can be considered a very good value.

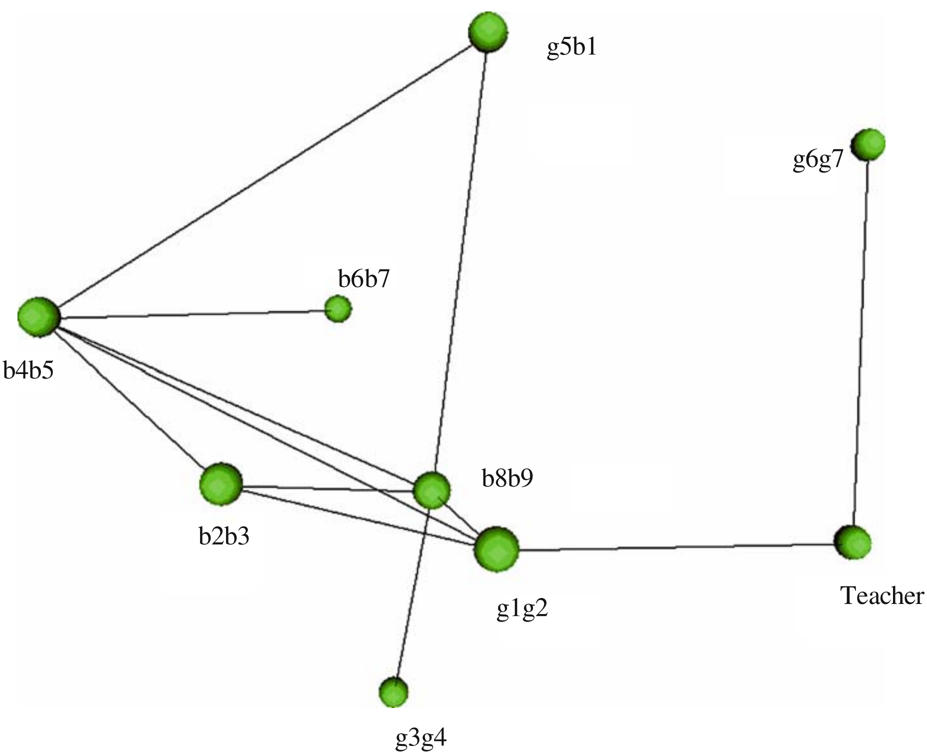

Figure 1 Patterns of networked interaction in joint problem solving

Frequent interaction can be seen as closeness in the mds-map (see Figure 1). In the map, student pairs situate close to the pairs from whom they have received or to whom they have sent comments. We can see that interaction is frequent and reciprocal especially among student pairs b2b3, b8b9 and g1g2, who are all closely situated. The interaction among the participants was defined as reciprocal when they had communicated with each other at least once. Further, in the mds-map, only the reciprocal ties are drawn; the non-reciprocal information is not visualized. The original information concerning the commenting is presented in Table 1.

In Table 1, the non-symmetric matrix of interaction is presented. It can be observed that the student pair b2b3 has sent five comments to clarify or specify their contributions in joint problem solving. Further, only the student pairs g1g2 and g6g7 have sent messages to the teacher. The teacher had sent messages to most of the student pairs.

The metacognitive quality of the students' computer notes

The metacognitive content of the posted computer notes was analysed by two independent coders following the ideas of validity of qualitative analysis (see Miles & Huberman, 1994). The computer notes (N = 95) were characterized as *metacognitive knowledge* including a person, task and strategy variables, *metacognitive skills* with the subcategories of planning, monitoring and evaluating, and *not metacognitive* notes. Two-thirds of the data were categorized to get extensive inter-coder reliability, which was 69% in the analysis of the metacognitive content of the student pairs' computer notes. In addition, Cohen's Kappa value (Cohen, 1960) was calculated. The inter-rater reliability is not high because the obtained Kappa was 0.53, which is below the commonly applied criteria of 0.70

The results of the qualitative content analysis show (see Table 2) that the student pairs use metacognitive task and strategy knowledge in joint problem solving. The most frequently observed categories of metacognitive skills are monitoring and evaluating, while comments concerning planning are non-existent. Concerning the person variable of metacognition, the participants either did not describe themselves as problem solvers, or they did not express how they were going to perform the problem-solving task. It may be that the missing features of metacognition (planning and the person variable) are present in joint problem solving even thought they are not visible in the process as written notes. It should also be noticed that the notes were posted by a student pair and not by individual students. The teacher was

Table 1 The frequencies between sent and received comments among student pairs and teacher

	b2b3	b4b5	b6b7	g1g2	g3g4	g6g7	b8b9	g5b1	Teacher
b2b3	5	5	1	5	1	0	3	1	0
b4b5	4	0	2	2	1	0	0	0	0
b6b7	1	2	0	1	1	0	1	0	0
g1g2	4	2	0	0	1	0	2	1	2
g3g4	0	0	1	1	1	0	1	0	0
g6g7	0	0	1	1	0	0	0	1	1
b8b9	2	2	1	3	3	0	0	3	0
g5b1	0	2	1	1	0	1	2	0	0
Teacher	0	0	1	2	1	2	1	0	0

Table 2 The metacognitive content of the student pair's computer notes

Student pair	Metacognitive knowledge			Metacognitive skills		
	Person	Task	Strategy	Planning	Monitoring	Evaluating
b2b3	0	1	0	0	1	2
b4b5	0	1	0	0	1	0
b6b7	0	0	0	0	0	0
g1g2	0	1	0	0	4	1
g3g4	0	0	0	0	1	2
g6g7	0	0	0	0	0	1
b8b9	0	1	1	0	3	2
g5b1	0	0	0	0	1	0
Teacher	0	2	3	0	0	1
M	–	0.7	0.4	–	1.2	1.0
SD	–	0.7	1.0	–	1.4	0.9

mostly responsible for mediating metacognitive knowledge, knowledge of the task and strategies during the discussion.

The results concerning how often the computer notes are directed to support the other pairs' problem solving and how often it is focused on the student pair's explanations of own thinking are presented in Table 3. The inter-coder reliability of the analysis was 95.1% and Cohen's Kappa was 0.87, which is a good level. The results show that, on average, the metacognitive computer notes were focused more on supporting other pairs' thinking than on regulation of the pair's own thinking.

Differences in the student pairs' metacognitive activity

In order to get an overview of how metacognitive activity varied among participants a correspondence analysis was performed. The results show that the mass value of the computer notes identifying metacognitive knowledge was 0.105, and 0.211 for metacognitive skills. The majority of the notes were not metacognitive notes, with the mass value of 0.684. The results of students' metacognitive profiles are presented in Table 4.

Table 3 The frequencies of the computer notes focusing on supporting student pair's own and other pairs' thinking

Student pair	Supporting pair's own thinking	Supporting other pairs' thinking	Non-focused
b2b3	2	2	18
b4b5	1	1	8
b6b7	0	0	7
g1g2	3	3	7
g3g4	1	2	3
g6g7	0	1	4
b8b9	3	4	7
g5b1	0	1	9
teacher	0	6	2
M	1.1	2.2	7.2
SD	1.3	1.9	4.7

Table 4 Participants' metacognitive profiles

Student pair	Metacognitive content of computer notes			
	Metacognitive knowledge	Metacognitive skills	Not metacognitive	Total
b2b3	0.045	0.136	0.818	1.00
b4b5	0.100	0.100	0.800	1.00
b6b7	0.000	0.000	1.000	1.00
g1g2	0.077	0.385	0.538	1.00
g3g4	0.000	0.500	0.500	1.00
g6g7	0.000	0.200	0.800	1.00
b8b9	0.143	0.357	0.500	1.00
g5b1	0.000	0.111	0.889	1.00
teacher	0.625	0.125	0.250	1.00
Mass	0.105	0.211	0.684	1.00

In Table 4, it can be seen that the teacher has a very different profile from all the student pairs. She was mainly responsible for bringing metacognitive knowledge to the joint discussions. The three student pairs, g1g2, g3g4 and b8b9, produced above average utterances categorized as metacognitive skills. However, the majority of the student pairs have some metacognitive skills with an abundance of non-metacognitive notes. The goodness-of-fit test was $\chi^2(16) = 39{,}865$, $p<0.01$ which can be considered a very good level. The variation in students' metacognition can now be visualized in a correspondence map in Figure 2.

Figure 2 shows that there are three main groupings on the correspondence map. As described above, most of the student pairs had a lot of non-metacognitive notes which can be seen as a grouping near the point of "not metacognitive". Only three student pairs were situated near the point of metacognitive skills. On the map only the teacher is located close to the point of metacognitive knowledge. The

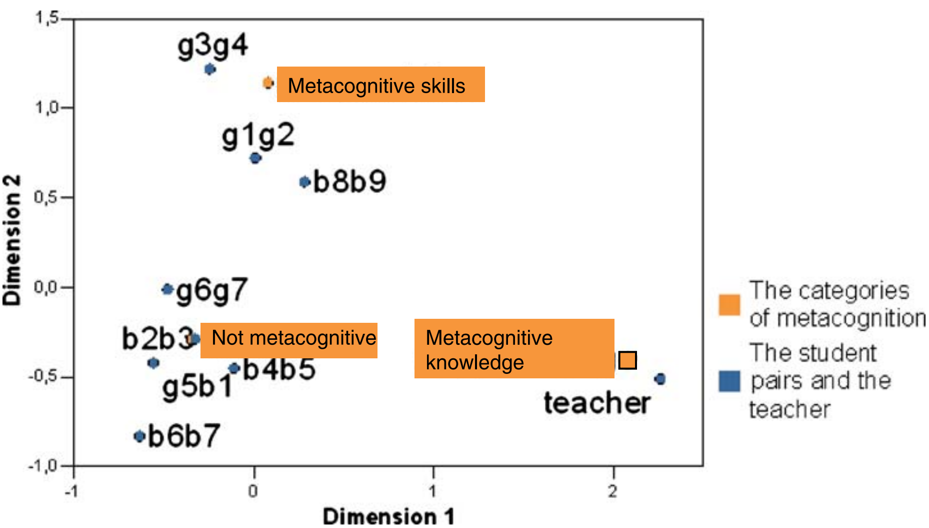

Figure 2 The student pairs' metacognitive profiles displayed as a correspondence map

Table 5 The features of networked interaction among participants

Student pair	Received	Sent	Size	Reciprocity* (%)	Betweenness
b2b3	4	6	6	66	1.8
b4b5	5	4	6	50	0.7
b6b7	7	5	8	50	3.5
g1g2	8	6	8	75	12.5
g3g4	6	3	6	66	0.4
g6g7	2	4	4	50	0.8
b8b9	6	6	7	71	3.8
g5b1	4	5	6	50	5.3
teacher	2	5	5	40	2.2
M	4.9	4.9	6.2	57.6	3.4
SD	2.0	1.1	1.3	12.1	3.8

*the degree of reciprocity $= \frac{\text{the number of mutual relationships}}{\text{the number of all relationships}} \times 100$

metacognitive skills subgroup occupies a central position on the MDS map. This subgroup may have a mediating role between the teacher and most of the student pairs.

The relationship between active participation and metacognition

Social network analysis, SNA, is a tool used to study social relations among participants. In this study it is used in order to examine to what extent the student pairs and the teacher received and sent comments from and to other participants, i.e. what is the size of their neighbourhoods in the networked discussion, how often the relationship is reciprocal and do they have a strategically important or meditative role (betweenness) among the participants. The results are presented in Table 5.

The results in Table 5 show that the student pair, g1g2, has received messages from all the other participants and that they have sent messages to the six other participants. The girls' network size was eight which means that they had had eight dialogue partner pairs, and 75% of these connections had been reciprocal. They also had a rather high betweenness value, 12.5. This means that the student pair, g1g2, has been a very active participant in the networked discussion, and that the pair has a lot of reciprocal connections. The analysis of the metacognitive content and the focus revealed that they also mediated metacognitive knowledge, and that regulatory activities were focused on the students' own understanding, as well as on providing help or support for the other student pairs. On the multidimensional scaling map, the pair was situated quite centrally in the network.

Pearson's correlation was performed between the metacognition and the social network analysis measures, and the results are presented in Table 6. The correlations between metacognitive skills, especially monitoring, and reciprocity appeared to be high (0.902, 0.831, and $p < 0.01$, $p < 0.01$). The correlation analysis also indicated that the student pairs seem to regulate their own understanding in reciprocal interaction (0.902, $p < 0.01$).

There were also participants who held a central position in the network; they participated in many ongoing discussions in which they clarified their own thinking

Table 6 Correlations among the variables

	Means, standard deviations, and intercorrelations among the study variables														
	1.	2.	3.	4.	5.	6.	6a.	6b.	6c.	7.	7a.	7b.	7c.	8.	9.
1. Received															
2. Sent	0.221														
3. Size	0.930*	0.476													
4. Reciprocity	0.663	0.369	0.524												
5. Betweenness	0.571	0.604	0.638	0.471											
6. MC-knowledge	−0.366	0.302	−0.191	−0.273	−0.023										
6a. Person variable	.	.	.	.	.	.									
6b. Task variable	−0.198	0.447	−0.045	−0.049	0.113	0.912*	.								
6c. Strategy variable	−0.446	0.169	−0.274	−0.401	−0.115	0.958*	.	0.756**							
7. MC-skills	0.550	0.440	0.436	0.902*	0.568	0.060	.	0.294	−0.109						
7a. Planning	.	.	.	.	.	.	.	.	.	.					
7b. Monitoring	0.653	0.529	0.589	0.831*	0.752*	−0.012	.	0.211	−0.167	0.943*	.				
7c. Evaluating	0.000	0.137	−0.111	0.634	−0.134	0.179	.	0.204	0.142	0.575	.	0.311			
8. Supporting other pairs' thinking	0.219	0.334	0.126	0.066	0.142	0.908*	.	0.826*	0.871*	0.373	.	0.268	0.467		
9. Supporting pair's own thinking	0.571	0.571	0.513	0.902*	0.498	0.54	.	0.325	−0.140	0.960*	.	0.902*	0.569	.307	
M	4.89	4.89	6.22	57.56	3.44	1.11	.	.67	.44	2.44	.	1.22	1.00	2.22	1.11
SD	2.088	1.054	1.302	12.063	3.768	1.616	.	.707	1.014	2.007	.	1.394	.866	1.856	1.269

*Correlation is significant at the 0.01 level (2-tailed).

**Correlation is significant at the 0.05 level (2-tailed).

. Correlation cannot be computed because at least one of the variables is constant.

and, thus, there was a strong correlation between monitoring and reciprocity (0.831, $p < 0.01$), and between monitoring and betweenness (0.752, $p < 0.01$). Metacognitive knowledge was mediated in discussions to support other participants' thinking, the correlation between supporting other pairs' thinking and metacognitive knowledge being high (0.908, $p < 0.01$). It should be noticed that high correlations, for example, between the task variable and metacognitive knowledge do not have a meaningful interpretation because the task variable is defined as a subcomponent of metacognitive knowledge. Although, not marked as significant, there are quite strong relations between supporting pair's own thinking and social network analysis measures: received and sent messages, and neighborhood size.

Discussion

The results of this study show that the students make their metacognitive thinking visible especially in reciprocal interaction with peers in a computer-supported collaborative learning situation. In the joint problem solving, the students are confronted with a learning situation where they are required to compare their own and their peers' thinking, which requires the use of metacognitive knowledge and the regulation of cognitive processes. It was found that there was some metacognitive activity which varied among participants in networked interaction. Although there was an abundance of not metacognitive computer notes, there were student pairs whose computer notes mainly identified monitoring and evaluating. These findings are consistent with previous studies (e.g. Goos et al., 2002; Iiskala et al., 2004) although in this study the communication is based on the written interaction. Further, the participants clarified their own thinking and supported their peers in problem solving (cf. Jermann, 2004).

The differences in metacognitive activity were examined with the correspondence analysis and three subgroups were found. The largest subgroup was formed by the student pairs for whom it was typical to send not metacognitive messages to the discussion. It may be that in this study the level of the discussion was not high enough to support the students' metacognitive thinking (cf. Jost, Kruglanski & Nelson 1998). On the other hand, these messages may have had an important role for the student pairs in keeping them on track in the discussions, and thus giving the experience of attendance. The second subgroup consisted of the teacher who was responsible for mediating metacognitive knowledge among the participants. Further, there was the third subgroup of student pairs who monitored and evaluated their own thinking and supported their peers in problem solving.

The description and the differences concerning the metacognitive content of the posted computer notes were related to the social interaction process. Networked learning environment can be used to provide an opportunity for social interaction and joint problem solving (De Corte, Verschaffel, Entwistle & Van Merriëboer, 2003) to the students. On the other hand, there is empirical evidence that computer based learning environments tend to have isolated messages without replies to them (Nurmela, et.al., 1999). In this study it was found that the student pairs formed a social network where they were actively discussing with each other. Our aim has been to study whether these active participants are also metacognitively central members of the group. Although a correlation between active participation in the discussion and production of metacognitive messages was not found, the participants who are situated in a strategic network position, i.e. in between other student pairs, seem to monitor and evaluate their learning processes more than their peers. These participants may have a mediating role between the teacher and most of the student pairs. It may be that the other participants' contributions to the discussion encourage the central student pairs to clarify their thinking.

In this study, the student pairs participated in joint discussion to share their ideas and thinking, a fact which also restricts the interpretation of the results. The students worked in pairs around the computer but the used data analysis is based only on students working through the computer. Therefore, there are no data on what happened between the students when they negotiated about how to reply to the messages sent by their peers, or whether the pair worked as two individuals side by side, and whether this had an effect on how they participated in joint problem solving at a metacognitive level. In future research, it would be essential to examine how the participants benefit from their peers' thinking and the social learning situation (cf. Salomon & Perkins, 1998), for instance, by following the idea of a stimulated recall interview where the participants could describe their working as a group or a student pair, and how the other participants' comments influenced on both an individual students' own and the group's own problem solving in networked discussion immediately the interaction is over. Thus, it would be possible to determine the role of shared metacognition in networked problem solving process.

Another purpose of this study was to find methods to combine social and individual levels of analysis. The four different analyses, the multidimensional scaling, the content analysis, correspondence analysis and social network analysis, were used in order to cover the diversity of the phenomena under study. The correspondence analysis and multidimensional scaling technique are both exploratory methods used to display the data as graphics to make the participation activity visual and to examine the structures of interaction. In both methods no statistical hypothesis is tested, and there are no requirements for the normality of the distributions. The methods have indicators like Chi-square statistics (in correspondence analysis) and stress-value (mds-map) which illustrate the goodness-of-fit of the model used. The number of participants was limited but the interpretations can still be made to a reasonable extent. The added value of the correspondence analysis was to provide information concerning the different types of metacognitive profiles.

It has been indicated that not only the amount of interaction but also its quality are important in computer-supported collaborative learning (Mäkitalo, 2006). Therefore, the computer notes were classified according to their metacognitive content. During the analysis it became clear that classifying notes into those with and those without metacognitive aspects is quite difficult (cf. Brown et al., 1983, 106–107). Further, the components of metacognition are closely intertwined (Schraw 1998; Schraw & Dennision, 1994) and sometimes separating them in a written computer note is a question of interpretation. Consequently, the content analysis of the computer notes should be developed further.

The contribution of the social network analysis was to enable both actor level and community level measures. It made it possible to combine the information related to the actor level with the interaction structure at the whole community level. In addition, the different social network analysis measures provide various information on the tie level, and are not only based on actor level attributes. The actor and community level measures were based on the active participation, while the passive participation was not taken into account. This aspect should be taken into account in future research. All the methods used gave some evidence of metacognition in a social context in networked learning. To conclude, the multi-method approach is needed and the challenge is then to combine the different result implications and the various methodological approaches which produced these results.

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