Patterns of scaffolding in computer-mediated collaborative inquiry

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Abstract

While the importance of scaffolding for student learning is acknowledged, models of individual and face-to-face scaffolding are not necessarily applicable to educational settings, in which a community of learners is pursuing a process of inquiry mediated by technology. Such communities may have special requirements and particular demands on tutors, and on scaffolding. The purpose of the present study was to assess three tutors’ contribution to university students' computer-mediated discourse organized according to progressive inquiry model. Quantitative and qualitative analyses were conducted to investigate the tutor’s role and scaffolding in the inquiry discourse. During the inquiry process, the more experienced two tutors acted more like metalevel commentators, whereas the less-experienced tutor participated to the inquiry almost as a co-inquirer by producing many questions herself. More elaborate scaffolding for supporting students’ metacognitive awareness of inquiry was lacking in all tutors’ notes. Implications for pedagogical improvement in collaborative, computer-supported educational settings are discussed.
Patterns of scaffolding in computer-mediated collaborative inquiry

The possibilities and challenges of computer-supported collaborative learning (CSCL) have been intensively investigated in recent educational research. Practices of problem-based inquiry seem to provide methods for facilitating students' intentional learning and knowledge building in CSCL (Lehtinen, Hakkarainen, Lipponen, Rahikainen, & Muukkonen, 1999; Scardamalia & Bereiter, 1994). Most of the studies on CSCL have, however, concentrated on students' activity; the teacher's or tutor's role has been much less often investigated. It is important that students not be left working among themselves without guidance in the collaborative learning process. An advanced learning environment can facilitate the process, but it does not by itself provide sufficient support for the structuring of the collaborative work.

Brown and his colleagues (1993) discussed the role of the teacher in discovery learning and argued that the teacher should take the difficult role of being in the middle ground of guided discovery learning. Too much control prevents students’ self-directed learning activity and restricts their cognitive efforts. On the other hand, teachers should not rely too much on students’ spontaneous inquiry, but should intervene if students are not able to make progress themselves.

The special, investigated case was a four-month university course in cognitive psychology, in which students pursued collaborative inquiry in groups, using asynchronous discourse system (Future Learning Environment) between weekly lectures, with the support of a tutor participating in each group. The course was organized according to the pedagogical model of progressive inquiry (Hakkarainen, 1998; Muukkonen, Lakkala, & Hakkarainen, in press), which is based on theories of knowledge building (Scardamalia & Bereiter, 1994), interrogative model of scientific inquiry (Hintikka, 1982; Hakkarainen & Sintonen, 2002), and distributed expertise in a community of learners (Salomon, 1993). In progressive inquiry, students’ genuine questions and previous knowledge of the phenomena are a starting point of a deepening process, in which students and tutors explain phenomena, share their expertise and build new knowledge collaboratively with the support of technology. The built-in inquiry scaffolds in FLE were intended to elicit practices of progressive inquiry.

In the present study, the focus is on the tutors' role and ways of scaffolding in the progressive inquiry discourse. It can be seen to consist of taking multiple perspectives on how the scaffolding and tutoring has been put into practice, as well as discussing and suggesting new models and critical issues for scaffolding and tutoring in computer-mediated collaborative inquiry. We will begin with proving a background by presenting earlier studies on scaffolding and tutoring.

Studies on scaffolding and tutoring

In the recent socio-cognitive approaches to learning, Vygotsky’s (see 1978) Zone of Proximal Development (ZPD) has been used actively as a relevant theoretical concept to model the importance of more competent participants’ contribution to a learner’s advancement. Mercer and Fischer (1993) have used the concept “neo-Vygotskian” to describe their approach to the development of a conceptual framework for understanding teaching and learning in educational settings as culturally based, social and situated activity. Theoretically, one can view a group of learners as having multiple overlapping zones of proximal development in a collaborative
learning situation (Brown & Campione, 1994). Nevertheless, the definitions of the ZPD did not specify the nature of the guidance, which would promote successful cognitive development.

The concept and definitions of scaffolding can be seen as an attempt to define more precisely, what kind of help the tutor should give to a learner (Wood & Wood, 1996). The concept was first introduced by Wood, Bruner, and Ross (1976) for investigating the help that an adult gives to an individual learner to perform a task that is too difficult for a child to accomplish alone. According to them, scaffolding included such elements as arousing the learner’s interest in the task; reducing the degrees of freedom—and hence the complexity of problem space—in the task to suit the learner’s level of expertise; directing the learner’s activity towards the task goals; highlighting the critical features of the task; helping to control frustration; and modeling the solution to a task.

However, the basic studies on scaffolding or successful expert tutoring (Wood et al., 1976; Wood & Wood, 1996; Lepper, Drake, & O’Donnell-Johnson, 1997) were based on individual tutoring situations, in which a tutor was guiding one individual learner. As Kolodner (2001) stated, models of individual scaffolding are not necessarily applicable for educational settings in which a community of learners is pursuing a common achievement.

Another feature in the studies of scaffolding and tutoring, mentioned above, was that the tasks that the learners tried to accomplish were rather formal, structured problems that had a known correct solution. In instructional settings where studying is intended to be research-like inquiry, the problems posed are often open-ended in nature; students are treated as experts who have knowledge to share, and they are encouraged to create new knowledge and explanations, rather than just state their opinions (Scardamalia & Bereiter, 1994; Paavola, Lipponen, & Hakkarainen, 2002). In such approach, teachers’ response is dedicated to furthering understanding (of scientific concepts), not to evaluating and reviewing, and the purpose is to promote students’ cognitive and metacognitive advancement, with support given only when necessary, in order to coach the students gradually to take upon themselves responsibility for higher-level aspects of inquiry (Bereiter & Scardamalia, 1987; Hogan & Pressley, 1997; Edelson, Gordon, & Pea, 1999; Muukkonen, Hakkarainen, & Lakkala, in press).

Wells (2000) argued that inquiry approach should not only change the organization of students’ activity, it should also characterize the teacher’s role in the learning community. He distinguished two levels at which the teacher needs to be involved in inquiry: (a) as a leader and organizer of the community's activities, and (b) as a co-inquirer with the students in the topics that they have chosen to investigate. In parallel lines, Hogan and Pressley (1997) argued that the prototypical one-to-one scaffolding model is impractical for group instruction in science teaching: “The teacher’s role within a community of inquiry is not so much to execute a set of specific strategies, but rather to organize the learning environment to establish an underlying culture that centers around thinking together with students.” (p. 88).

In addition, if the communication of the participants in the community of learners is mediated by technology, it changes the nature of scaffolding and tutoring furthermore. Tutors have to learn new ways to support students’ work through asynchronous communication channels, compared to more familiar ways in face-to-face contact (Lakkala, Ilomäki, Lallimo & Hakkarainen, 2002). Most earlier studies and models of teachers’ or tutors’ contribution to group
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learning or collaborative inquiry are still based on face-to-face group instruction or classroom settings (Roehler & Cantlon, 1997; Hogan & Pressley, 1997; Mercer & Fisher, 1993; Levin, 1999).

Ahern, Peck, and Laycock (1992) studied university teachers' role, especially, in computer-mediated learning discussions. They compared the effects of three different styles of teacher discourse (questions only, statements only, and conversational) in computer-mediated discussions in an undergraduate university course for eighty students. In the question-only condition, students' responses tended to concentrate on the topics selected by the instructor. The statement-only condition produced more complex interactions in terms of the length and complexity of discourse threads. The conversational style was the most effective in encouraging students' exploration and engagement into collaborative inquiry; measured, for example, by the amount of peer-peer interaction. This evidence suggests that, in the computer-mediated inquiry process, teacher or tutor has an important role in promoting and modeling the culture of collaborative inquiry during the process.

The teacher is very often at the center of discussions in traditional teaching, and the technology does not necessarily, by itself, change the situation. Guzdial (1997) reported findings about the teachers’ and tutors’ dominant role in college courses, in which a CSCL forum was used. In eight courses out of ten, it was the teacher or teaching assistant who produced the highest number of notes; also, the second most productive writer was the teaching assistant in three of the ten courses. Seitamaa-Hakkarainen, Lahti, livonen, and Hakkarainen (in press) investigated computer-supported participatory designing in a university-level design course, in which the progressive inquiry approach was used. Also in their studies, one of the most striking results was the teacher’s cognitive centrality (Stasser, 1999); the teacher mediated a great deal of interaction between the students. Seitamaa-Hakkarainen and her colleagues raised questions about the inquiry-hindering effects of such centrality.

In our previous study (Muukkonen, Hakkarainen, & Lakkala, 1999), we investigated the use of FLE in an undergraduate media-education course following progressive inquiry, in which there were no tutors participating in the asynchronous discourse. The knowledge produced by the students was analyzed by categorizing the ideas in students’ notes according to their inquiry nature. According to the results, the students produced a lot of Problems (26%) and Working theories (39%), and some Quotes to another students’ ideas (16%) and Metacomments (13%), but the amount of Scientific explanations was very low (6%), compared to the objectives of progressive inquiry to support student to deepen their explanations with the use of theoretical knowledge sources.

In the next study (Muukkonen et al., 2001), we analyzed, in a similar way, the knowledge produced by the students in the course, in which there was also tutors scaffolding the FLE discourse. In this course, the general pattern of students’ knowledge productions was almost similar to the previous course: Problems 21%, Working theories 40%, Metacomments 17%, Scientific explanations 12%, and Quotes 10%. The difficulty in promoting students’ application of scientific theories in their discourse appeared to be a challenge for scaffolding the community of learners pursuing progressive inquiry, to deepen their shared explanations. Therefore, we got interested in the tutors’ activity in the course.
The purpose of the study

To sum up, in investigating scaffolding and tutors’ role in computer-mediated collaborative inquiry, there is a need for new framing because of the following novel features in the educational setting: (a) There is an inquiry approach which is based on challenging open-ended authentic problems, not previously formulated tasks that have a right answer; (b) there is emphasis on collaborative group work and knowledge creation instead of individual tasks and accomplishments; and (c) there is technology-mediated communication instead of or in addition to face-to-face interaction. The purpose of the present study was to investigate the tutors’ activity and efforts to scaffold the progressive inquiry discourse. The questions addressed were a) what was the tutors’ role and contribution in university students’ computer-mediated inquiry discourse; and b) how the tutors succeeded in applying the theoretical principles of progressive inquiry in their scaffolding practices; and c) what recommendations can be given, based on the results, to develop the models and practices of scaffolding and tutoring of computer-mediated collaborative inquiry.

Method

Setting

The data were collected from a 15-week university course on “Psychology of Learning and Thinking II”. The course consisted of weekly 2-hour lectures, and tasks between the lectures. Eighty students took part in a course, and they were divided in two conditions, so that 17 of them volunteered to use the Future Learning Environment (FLE) between lectures for collaborative inquiry. This study is based on an analysis of these 17 students’ and three tutors’ written postings to FLE’s collaborative database. The students in the other condition did not use any groupware, but participated in the course in a more traditional format, following lectures and writing learning logs between the lectures. Comparison of all students’ knowledge productions in the two conditions has been reported in another study (Muukkonen, & al., 2001).

As mentioned already, the course was organized according to the principles of progressive inquiry. The following elements are being explicated (Muukkonen et al., 1999) to structure the progressive inquiry process (see Figure 1): (a) Creating the Context: In the beginning of the process the teacher creates a context in order to anchor the problems being investigated to central conceptual principles of the domain or complex real-world problems. The learning community is established by joint planning and setting up common goals. (b) Setting up research questions: An essential aspect of progressive inquiry is generating students’ own explanation-seeking questions to direct the inquiry. The whole studying in progressive inquiry is a problem solving process. (c) Constructing working theories: A critical condition of developing conceptual understanding is generation of students’ own theories, or interpretations for the phenomena being investigated. It is important that phenomena are explained with existing background knowledge before using information sources, and to openly share these self-explanations in the learning community. (d) Critical evaluation: Critical evaluation addresses the need to assess strengths and weaknesses of different theories and explanations produced, in order to direct and regulate the learning community’s joint cognitive efforts, and evaluation of the process itself. (e) Searching deepening knowledge: Explanatory scientific knowledge is essential for deepening understanding. A comparison between intuitive working theories produced and
well-established scientific theories tends to make weaknesses and limitations of the community’s conceptions explicit. (f) Generating subordinate questions: The process of inquiry advances through transforming the initial big and unspecified questions into subordinate and, frequently, more specific questions, based on the evaluation of produced new knowledge. Formulation of subordinate questions refocuses inquiry. (g) Developing new working theories: New questions and scientific knowledge that the participants come about give arise for new theories and explanations. The process includes publishing of the summaries and conclusions of a community’s inquiry. (h) Distributed expertise: All phases of the process should be shared among participants, in this case using collaborative technology. Diversity in expertise among participants, and interaction with expert cultures, promotes knowledge advancement. It includes shared cognitive responsibility of the success of inquiry.

--Insert Figure 1 about here--

Firstly, all the students were guided during the first two lectures to formulate research problems. Initially, they produced the research problems individually, continued by discussing their problems with a peer and, finally, within a small group, selected together the most interesting question to pursue. These questions were then presented to all the participants in the lecture, e.g., “How does motivation affect learning?” or “What is intelligence and how can it be measured?” After this initial problem setting, the questions were grouped together in three lists, consisting of 2-3 questions, to be further studied in FLE in three separate groups. In addition, the teacher gave one common problem to all groups: “How to overcome the constraints of human intelligent activity?” In all, 17 students volunteered to work with FLE between weekly lectures, and the students chose themselves the questions to investigate (and hence the group in FLE). The groups consisted of four to seven undergraduate students.

The requirement for course credit was to contribute actively to the progressive inquiry process in FLE by writing own questions and explanations, and by reading and commenting on productions of other members of the group. Information sources used were the weekly lectures and several scientific articles distributed by the teacher. At the end of the course, the students were also expected to write a summary of their own contributions and learning process to FLE.

The tool used in the investigated course, Future Learning Environment (FLE), is an asynchronous groupware system developed by the Media Laboratory, University of Art and Design, Helsinki, in collaboration with our research group in the Department of Psychology, University of Helsinki. It is designed for supporting collaborative knowledge building and progressive inquiry in educational settings (Leinonen, et al., 1999; http://fle.uiah.fi). FLE is an Open Source and Free Software, and the development of the system continues further (see http://fle3.uiah.fi).

The pedagogical model of progressive inquiry is embedded in the FLE design (Muukkonen et al., 1999). The Knowledge Building module provides a shared space, in the form of a threaded discourse forum, for working together for solving problems and developing ideas.
and thoughts generated by the participants. In the investigated course, a new KB area was founded for each starting problem formulated in the first lectures, and students were guided to continue the discourse by writing more specific problems, explanations and scientific knowledge under each starting problem. The notes were visible to all members in the same study group. In addition, for each group, one discourse forum was founded for the general discussion of the ways of working in the course. In the KB module, progressive inquiry is promoted by asking a user who is preparing a note to categorize the note by choosing a category of inquiry scaffold -- in the same way as in CSILE (Scardamalia et al., 1989) -- corresponding to the progressive inquiry model (Problem, Working theory, Deepening knowledge, Comment, Metacomment, or Summary). In addition to the KB module, the environment provided each student with a Virtual WebTop for storing documents. Each participant’s WebTop is freely available to all participants of the same course, which facilitates and promotes openness and sharing of produced knowledge. During the investigated course, the WebTops were used, in small extent, for sharing study materials, articles and editable documents, but their contents were not analyzed in this study.

Providing each group with a tutor participating in their FLE-work actualized the scaffolding during the inquiry process in the investigated course. The tutors were acquainted with the principles and goals of progressive inquiry, but they did not get any explicit and specific guidance about the ways that a tutor should contribute to the FLE discourse. The tutors did not meet the students in person during the course, but participated to the students’ work only through FLE. The teacher in the course, who gave the lectures, sent one starting note to each FLE group, but did not otherwise participate in the FLE-work. In any case, the teacher’s contribution for sharing theoretical and scientific information to students was crucial. Students had lively conversations with the teacher about the issues in the course during the lectures, but they have not been recorded or documented in this study. The present research concentrated on the analysis of the tutors’ activity and contributions in FLE.

Participants

The students in the course were undergraduate students from all the faculties of the university of Helsinki. They had a previous course in "Psychology of learning and thinking I" before enrolling for this course "Psychology of learning and thinking II". The mean grade (on a three point scale, with 3 being the highest) from the prior course was for the 17 members of the FLE groups 2.2 (SD = .72). The participants took part in this two-credit course to complete a ten-credits minor unit in psychology, which was offered to degree students at the University of Helsinki. Therefore, the backgrounds of the students were in most of the different fields of studies at the University of Helsinki, including forensics, mathematics, history, languages, and education. The age of the 17 students varied from 21 to 30, mean was 24 years. Average year in studies varied from 0 to 6 years, average was 3rd year. The majority of students taking part in the course were females, which was also reflected in the gender distribution of the FLE groups: 5 males and 12 females.

The three tutors were post-graduate psychology students, all females, who were members of the research group conducting this research. Tutors were 30 (tutor 1), 39 (tutor 2) and 26 (tutor 3) years old. Tutors 1 and 2 had a lot of teaching experience as lecturers in adult education, or in university. They also knew the theoretical basis of progressive inquiry very well, and Tutor 1 had participated to the design work of FLE, but they had not participated in actual tutoring in
progressive inquiry process. Also the youngest tutor was familiar with the basics of cognitive psychology and the progressive inquiry model, but she did not have earlier teaching or tutoring experience, and she was a newcomer in the research group.

Data collection and analysis

All the threaded discourse material produced by the three study groups to FLE’s database constituted the data analyzed in this study. In Table 1 is a summary of the data used.

Quantitative measures of the tutors' contribution. Several quantitative measures of the features of the amount of students’ and tutors’ activity in inquiry discourse--such as the number of the postings, and the number of starting notes and reply notes--were counted from FLE’s database. The amount of produced knowledge was also examined by dividing all message texts into segments, each representing a separate idea. To analyze the reliability of segmentation, an independent coder classified approximately 5% of all notes. The inter-coder reliability (single measure intraclass correlation; see McGraw & Wong, 1996) was .88, indicating that the reliability of segmentation was satisfactory. We also analyzed how tutors and students used the category of inquiry scaffolds (Problem, Working theory, Deepening knowledge, Comment, Metacomment, and Summary) in FLE’s Knowledge Building module to mark their notes. The teacher’s three starting notes were not included in the analyses.

Analysis of scaffolding. The three tutors' notes to FLE database were separately analyzed more closely by methods of qualitative content analysis (see Chi, 1997) to assess their ways of scaffolding and guidance in the discourse. The segmentation of note texts into ideas was used in the categorization of content. The categories of scaffolding were derived from the several preliminary analyses of the data. The following four categories, representing the scaffolding found in the three tutors’ notes, were used in the final classification:

1. Ask explanation-seeking question: Ideas assigned to this category were research questions into the inquiry process, questions about refocusing the discussion or questions directed explicitly to students to elaborate their explanations.

2. Produce expert's explanation: Ideas in this category represented the tutors' own explanations of the problems discussed or references to scientific explanations or theories.

3. Review and evaluate the discourse: Ideas assigned to this category included summaries or reviews of the discourse, references to students' contribution, positive and supportive evaluation or unmodified quotations from students' texts.

4. Recommend study practices: Ideas assigned to this category represented instructions for working in the course or in the inquiry process, and technical advice about FLE.
As a reliability test, an independent coder classified about 40% of ideas in the tutors’ notes. The coefficient for rater agreement (Cohen’s Kappa; see Cohen, 1960) was .89, which was considered good.

The effect of the tutors’ contribution to the students’ activity in the computer-mediated discourse was, further, evaluated by examining, which kind of tutors’ notes the students had responded to. Tutors' notes were classified as notes that were replied to (led to at least one further note in the discourse thread) and notes that were not replied to (ended the thread or sub-thread) in FLE’s Knowledge Building. Then these two types of notes were compared according to the proportions of the various categories of scaffolding they included.

Results

Quantitative measures of the tutors’ contribution

The students posted 203 notes, 11.9 notes per student on average (minimum was 3, maximum 33 notes), to FLE’s database during the course. Tutors posted 35 notes, 11.7 notes per tutor on average.

In all forums together, there were 83 top-level notes (34% of all notes), which were considered as new initiations in the discourse. Of those notes, 40 (48%) were isolated notes that did not have any reply notes following, and 43 (52%) were notes that had at least one reply note; e.g., they had started a new discourse thread. Mean number of notes in the discourse threads (in the threads that included at least two notes) was 4.65 (SD = 3.89). The shortest threads included two notes; the longest included 20 notes.

In Table 2 are presented the amounts of posted notes and sent and received reply notes by tutors and students (on average) in each group. We wanted, especially, to compare, if the tutors acted more like active initiators of new discourse openings, or did they rather react to students’ notes, to examine the tutors’ cognitive centrality in the discourse. It was analyzed by measures of sent and received reply notes to other participants’ notes.

--Insert Table 2 about here--

The frequency analysis indicated that there were substantial differences among the three study groups, and between the students and the tutors, in terms of activity in participating to the progressive inquiry discourse. Tutor 2 was the only tutor who produced more notes than students on average in the same group, but not any of the tutors was the most active participant in their group. Big majority (89%) of the notes sent by Tutor 1 were replies to the students’ notes, whereas Tutor 2 posted 63% as replies, and Tutor 3 only half (50%) of her notes as replies, the rest were starting notes. However, the students hardly at all replied to the notes of Tutor 1 and Tutor 2, whereas Tutor 3’s notes were frequently replied to, compared to the number of her notes.
and the average replying in her group. In general, there were longer discourse threads in the discourse of group 3, which indicates that the discourse was more sustained in that group than in the other two groups.

Every note posted to FLE’s Knowledge building had to be labeled using category of inquiry scaffolds based on progressive inquiry model. From the posted notes, we counted how the tutors and students used the inquiry scaffolds to represent the contents of their notes (see Table 3).

--Insert Table 3 about here--

The students classified over 50% of their notes as Comments. The tutors also used that inquiry label frequently, but less than students. That scaffold is maybe easy to use, if you are replying to someone else’s note. In any case, it does not work very well as a scaffold for helping the higher level thinking processes, if it is used like a “default” when replying to others’ ideas. The tutors used the inquiry label, Metacomment, in over 40% of their notes, which indicates that they themselves considered their role to be metalevel process organizers and evaluators rather than equal participants in the process.

Most of the produced notes were rather long and included many elements of progressive inquiry. In Table 4 there is an example of the three first notes in a discourse thread of nine notes concerning the main problem “How to overcome the constraints of human intelligent activity?” in Group 3. The general style of the discourse in all the three groups resembled a lot this kind of topic-centered conversational style manifested in this example.

--Insert Table 4 about here--

All the text in the notes was segmented to ideas. Students' 203 notes included 1353 ideas, 6.7 ideas per note on average. Tutors' 35 notes consisted of 159 ideas, 4.5 ideas per note on average. Tutor 1 had 40 ideas (4.4 on average per note), Tutor 2 had 56 ideas (3.5 on average) and Tutor 3 had 63 (6.3 on average) ideas in the notes. As can be seen, notes of Tutor 3 included on average more ideas than the other tutors' notes, almost as many as students' notes.

The tutors' scaffolding practices

First, we looked at the overall style and function of the tutors’ notes (N=35) in the discourse. About 60% of the notes concentrated mostly on the contents of the inquiry. The following example is a reply note of Tutor 2 in the middle of the discourse thread of eight notes, in which the students of Group 2 wondered how the concept of intelligence could be formalized:

Problem 1999-04-07 12:15 Tutor 2: Do we need the concept of intelligence?
If the concept of intelligence is so vague, should we stop using it in scientific and formal discussions? Would it be better to use the sub-concepts that Pekka mentioned (memory, ability to learn, ability to concentrate etc.), which can be better defined and more accurately measured.

About 40% of the tutor's notes mostly handled issues of study methods, inquiry process and practices in the course. The following example is written by Tutor 1 as a reply to a male student’s note, which included a request for other students in Group 1 to read an essay he had written earlier about human learning:

Metacomment 1999-03-29 12:44 Tutor 1: Writing the learning logs

I want to remind you that writing of own learning logs is one of the requirements for course credit, and everybody has to remember to take part in it. Of course now (as in many other issues) you who are active and read notes, also get this note first, although it is not meant for you. Tell others about this reminder in your group. In this discussion all the participants have produced very interesting and meaningful notes, so continue this work that has started so well!

One fourth (9 notes, 26%) of the tutors’ notes was directed to individual students, concluded from the explicit form of address in the text (“It is good that you have participated actively to the discussion about the importance of motivation in learning. Can you explain, in more detail, why highly motivated person gain better learning results than poorly motivated person?”). They were posted to the common KB forums as replies to some note, but their form of address resembled that of a private message. All the other notes were explicitly addressed to all students, or were just notes to common discourse without any addressee specified.

The contents of the tutors' notes were further analyzed in details, using a scaffolding-oriented coding scheme, to inspect their guidance activity. The tutors' notes were divided into 159 ideas, and each idea was classified to one of the scaffolding categories.

Most ideas in tutors’ notes belonged to the category Ask explanation-seeking question (58 ideas, 36.5 %). About half of them were subordinate questions to the main research problems handled in the discourse (“Is it even possible to describe intelligence in some sub-domain in an absolute way?”). In other questions, the tutors explicitly asked students to elaborate their explanations (“Can you explain more closely, why a motivated person achieves better learning outcomes than unmotivated person?”), or to focus the inquiry (“Could you start by defining, what intelligence is?”).

The category Produce expert's explanation (36 ideas, 22.6 %) included, mostly, the tutors’ own explanations to inquiry questions ("Apparently, intelligence is also always relative, so that a person is intelligent in some domain when compared to other people."). About one third of the explanations were references to some scientific theory, source or concept ("I suppose you know Vygotsky's theory of the Zone of Proximal Development, according to which cognitive development occurs in social interaction, where one member of a group is more able than the other [this can also be called vertical interaction; from top down, from bottom up]. ").
Ideas in the category Review and evaluate the discourse (39 ideas, 24.5 %) included almost as many neutral summaries of the discourse process ("I think that earlier notes have dealt with both general thinking skills [Matti's first note] and learning content in some domain [Paula's first note]", unmodified quotations from students' notes, and positive and supportive evaluations of the process ("Good start for an important topic").

In the scaffolding category Recommend study practices (26 ideas, 16.4 %), the tutors gave, mostly, rather general advice for studying ("You have to ask the teacher about his evaluation"). Every tutor wrote one or two reminders about the importance of active participation in the FLE-discourse (see above), although it is very difficult to say, if these kind of general reminders are effective. A few ideas concerned technical advice of using FLE's tools. Only about one fourth of the ideas were recommendations for sophisticated inquiry practices ("Next you could, for example, take into account the comments and define more specific working theory or problem that you first try to answer"). In the tutors' notes, there was no guidance that can be said to focus explicitly on advancing metacognitive awareness of the students.

Table 5 presents the frequencies and relative proportions of categories of scaffolding in the three tutors' notes. According to $\chi^2$-test there was a significant difference between the tutors, $\chi^2 (6, N = 159) = 18.32, p < .01$. Cell-specific exact tests (Bergman & El-Khoury, 1987) were carried out in order to examine whether the observed frequencies in each cell deviated from what could be expected by chance alone.

It is interesting that the nature of the knowledge produced by Tutor 3, who was less experienced as a tutor and in the content area, differed most from other tutors’ postings. As can be seen from Table 6, Tutor 3 generated relatively more questions and less study recommendations and expert explanations compared to the other two tutors. Tutors 1 and 2 produced fewer questions than could be expected by chance alone, compared to tutor 3. Tutor 1 acted most evenly by giving as much different kind of scaffolding.

In addition, we wanted to compare, if the tutors’ notes that the students had responded to differed from the notes that had not received any replies, and, therefore, had ended the discourse thread. As mentioned earlier, the notes of Tutor 3 had been replied to relatively more by the students than the notes of Tutor 1 and 2, but we wanted to examine, using the coding of more detailed content analysis, if there were some crucial differences in all the replied-to and not-replied-to tutor notes. Further analysis revealed that from the 35 tutors' notes, 15 were replied, 20 were not replied. On average, there were 4.7 ideas in replied-to notes and 4.2 ideas in not-replied-to notes. Figure 2 shows the proportions of the scaffolding elements in the tutors’ notes of both types. According to $\chi^2$-test there was a significant difference between the frequencies, $\chi^2 (3, N = 159) = 23.37, p < .005$. Cell-specific exact tests (Bergman & El-Khoury, 1987) revealed that the replied-to tutors’ notes included more explanation-seeking questions ($p < .001$) and less recommendations for study practices ($p < .01$) than could be expected by chance alone, whereas
the not-commented-notes included, contrariwise, less explanation-seeking questions (\(p < .005\)) and more recommendations for study practices (\(p < .05\)) than could be expected by chance alone.

--Insert Figure 2 about here--

In the not-replied-to notes there were more and in the replied-to notes less guidance focusing on concrete study practices. It is understandable that students did not comment on these recommendations; instead, they either acted according to the guidance or ignored it. For example, Tutor 2 advised three students to choose a research problem and continue the discourse under that question in FLE’s Knowledge Building, and the students acted accordingly, without explicitly replying to the tutor’s note.

A most interesting result is the high proportion of questions in replied-to notes. Practically all the questions that tutors produced were explanation seeking in nature, and notes that contained this kind of questions appeared to inspire the students to continue the discourse.

Conclusions and discussion

The definition of scaffolding implies that the guidance given to learners should be directed, especially, to issues that are difficult for them, or beyond their reach without guidance. In the investigated university course, the goal was to elicit deepening, sustained question-driven inquiry in a community of learners. Support for this collaborative learning challenge was given to students by organizing their work according to the model of progressive inquiry, and by providing them with collaborative technology (Future Learning Environment) that included built-in scaffolds to structure the inquiry. In addition, a tutor participated in each study groups’ work in FLE. The special focus in the study was on the tutors’ contribution in the computer-mediated inquiry.

There are many aspects that can be examined of a tutors role in scaffolding computer-mediated collaborative inquiry: for instance, should the tutor take an active role of an expert model in contributing to the process, or leave the students to work as much for themselves as possible; should the guidance during the discourse be directed to individuals or to the community; or how to give guidance that helps the learners gradually take upon themselves responsibility of cognitively more challenging tasks in the inquiry. According to the goals of progressive inquiry, a tutor should explicitly try to deepen students’ inquiry by guiding them to formulate more specific problems and higher-level theoretical explanations, encourage the students to collaborate and build-on each others’ ideas, and to plan, monitor, and evaluate the inquiry process themselves.

To define goals for the development of computer-mediated discussion forums, Guzdial and Turns (2000) argued that effective learning is more likely when the discussion is sustained and on-topic. In broad terms, this entails that the scaffolding, provided by the environment and the tutors, should invite students to produce more elaborations on a started thread of a discussion. In the present study, the comparison of the differences in the contents of the tutors' replied-to and
Patterns of scaffolding

not-replied-to notes revealed that those notes, to which the students had replied, included relatively more explanation-seeking questions than the notes to which there were no replies. Consequently, if the aim of tutoring is to activate computer-mediated discourse, one way might be to generate stimulating questions to the discourse forum. However, in progressive inquiry the aim is to promote students themselves defining good research questions and directing their inquiry. In the investigated course, the students might have concentrated on answering the tutors’ questions, instead of trying to generate their own questions. Students’ activeness, or long discourse threads, does not necessarily guarantee that the goal of deepening inquiry process is met.

Our earlier studies of the students’ knowledge productions with the support of progressive inquiry and FLE software (Muukkonen et al., 1999; Muukkonen et al., 2001) imply that the approach fostered the production of students’ own questions and explanations, and the content of the students’ computer-mediated discourse was very “on-topic” and “on-task” in nature, but not very deepening; the elaboration of own explanations into more theoretical explanations was not so evident in the students’ work. The externalization of students’ own intuitive working theories, and own activity in defining the questions to pursue, is often the most demanding aspect in progressive inquiry for students who are used to traditional instructional practices. At the same time, it is important also to promote the use and elaboration of well-established scientific theories for deepening the community’s understanding.

According to the results of the present study, the tutors were not the most active participants in their groups, and, consequently, managed to hand over responsibility of the discourse to the students. The tutors’ frequent use of the inquiry scaffold, Metacomment, indicated that the tutors tried to act more like process organizers and facilitators rather than participants in the inquiry. However, the tutors’ notes included a lot of problems and explanations of the content of inquiry; therefore, the tutors appear, actually, to have acted as co-inquirers or expert participants in the discourse. The tutors wrote also elaborate evaluations and reviews of the process, which resembled rather traditional way of considering the task of evaluation as a teachers’ responsibility. In addition, most of the explicit guidance in the tutors’ postings concentrated on rather practical issues, such as using information sources, or organizing the work in FLE. The guidance did not, on the present evidence, draw the students’ attention to the higher-level metacognitive tasks of planning, monitoring and evaluating the inquiry process themselves. The tutors did not, for example, explicitly advice the students to evaluate critically the produced ideas, to sum up the discourse, or to build on each other’s ideas.

In a research on pre-service teachers’ telementoring practices, Hewitt, Reeve, Abeygunawardena, and Vaillancourt (2002) ended up to a very similar classification, as was used in the present study, of the guidance in the teacher candidates’ contributions to elementary school students’ inquiry through Knowledge Forum software: requesting information, reporting information, encouragement and process functions. They concluded, likewise, that the teachers manifested a quite traditional instructional teacher-led style: their notes contained a great deal of encouragement, and questions and statements relating to the content area, but there was a relatively small number of process guidance to help students manage the inquiry themselves. Perhaps one additional challenge for scaffolding students’ metacognitive advancement in the investigated course, as in the setting studied by Hewitt and his colleagues, arose from the computer-mediation of the communication, and the lack of face-to-face interaction. It is not easy
to explain and advise regarding complex issues by simply writing notes to a threaded discourse forum. The virtuality of communication may have an effect on the way tutors write their notes, to be understandable for everyone, and not too complex. We may argue that not all scaffolding is even possible to transform to computer-mediated communication, but requires face-to-face interaction instead. This should be taken into account in organizing the educational settings using collaborative technology.

One relevant question is -- when the communication takes place in a shared database -- whether the tutor should give mainly general guidance to the whole community, or also individual guidance. The tutors in the present study had a mixed solution; some notes were explicitly directed to individual students, others were meant for common discourse. For example, O’Neill and Scardamalia (2000) emphasized the importance of the openness of online-mentoring discourses for helping less-competent students to develop more sophisticated ideas about the kinds of guidance they wanted from their “telementors”; the students could “peek” into the telementoring dialogues of other students, and use them as models for their own telementoring relationships. We may conclude that it is a benefit for all members of the learning community, if also the individual guidance is given openly through the shared database.

The comparison of the three tutors’ ways of contributing to the inquiry discourse revealed interesting differences in their modes of action. The two more experienced tutors mainly replied to the students’ notes, instead of writing new starting notes, but they did not get many replies to their notes from the students. The third, less-experienced tutor appeared to have taken a somewhat different role in her group: she produced longer notes and relatively more starting notes, and the proportion of problem statements in her notes was much greater than in the notes of the other tutors. In addition, her notes got plentiful replies from the students in her group. The discourse style of Tutor 3 can be compared to the question-asking style of teacher discourse, which was observed by Ahern and his colleagues (1992) to derive to discourse concentrated on topics chosen by the teacher.

The different activity patterns of the three tutors can be examined using the approach proposed by Bereiter and Scardamalia (1987; Scardamalia, 2002). They have described teacher’s role, in the light of knowledge building pedagogy, by separating teacher models A, B, and C. Teacher A’s focus is on formulating tasks and organizing activities of students without taking cognitive responsibility of students’ learning and knowledge building. Teacher B, in contrast, assumes him- or herself the cognitive responsibility by asking questions and explaining the issues being investigated. Teacher B is so much involved in inquiry process that he or she may be regarded as a co-inquirer rather than only a coach of the students. Teacher C, in turn, engages in an intensive effort to get the students to pose questions themselves as well as pursue their own explanations. Teacher C does basically everything that teacher B does but tries to make the students do it themselves. Toward this end, teacher C tries to create a culture that promotes students to pose questions, elaborate explanations as well as contribute to each other’s ideas, which is consistent with the goals of progressive inquiry.

Tutor 3 can be interpreted to have expressed the practices of the Teacher B model by generating a lot of questions and discourse openings herself and, hence, partly directing the content of the inquiry. She acted more as an active participant and an initiator of new wonderment in the inquiry process, rather than a facilitator of the students’ process. It could be
argued that the more experienced two tutors, who were also more acquainted with the theories behind the progressive inquiry model, were in the intermediate position between the Teacher B model and the Teacher C model. They appear to have tried to move from their own active participation to fostering students to take responsibility of the inquiry, but their scaffolding mainly concentrated on very practical study issues, and they also produced themselves a rather great number of expert explanations to the discourse. It appears to be, as Scardamalia (2002) stated, a significant and challenging learning accomplishment for teachers to move from approving the Teacher C model to the point where they actually practice it. Therefore, in addition to theoretical knowledge of advanced pedagogical models and approaches, the university teachers and tutors have to learn to reflect critically on their own scaffolding practices. The benefit of collaborative technology in this challenge is that the process is saved to the shared database, which makes it possible to analyze and evaluate the tutors’ activity afterwards.

The primary purpose of the present study was not to investigate the functionality of the built-in inquiry scaffolds in FLE. Nevertheless, the frequent use of the very neutral inquiry scaffold, Comment, especially by the students, raised the question of further developing adequate progressive inquiry scaffolds. The same result was found in a previous study of FLE usage (Muukkonen et al., 1999): students were not always able to use cognitive scaffolds adequately, but showed a bias for selecting a very neutral Comment scaffold. Developing the technical implementation of the scaffolds can, partly, help to overcome this problem. For instance, in version 3 of the FLE system, the following changes have been made to the functionality of the built-in scaffolds: the inquiry scaffold, Comment, has been left out from the inquiry set; some textual hints and recommendations are added to the situation, in which the user is choosing a certain inquiry label; and the choice of inquiry label is “forced” in a way that a user always has to make a choice about it in a new note (see http://fle3.uiah.fi). In the first version of FLE, which was used in the investigated course, the inquiry label of the replied note was automatically given to the next note, if the user did not change it.

Nevertheless, it is also essential to provide guidance and support for students in using the scaffolds appropriately; it is one way to try to increase students’ metacognitive awareness of the inquiry process. In the investigated course, the students got an explanation of the idea and functionality of the inquiry scaffolds in the beginning of the course, but the tutors did not, according to the analysis of their notes in FLE, follow up with any feedback on the use of the scaffolds to the students during the course. Puntambekar and Kolodner (1998) argued that in complex learning environments, not all of the scaffolding could be provided with any one tool but needs to be distributed across the various agents that play a role in learning. Probably the most effective approach, in promoting the desirable advancement in students’ learning and activity in an educational setting, is a successful integration of various modes of scaffolding, embedded in the pedagogical approach, tasks, and tools, and manifested in the human tutors situation-specific guidance. We suggest three complementary levels that need to be examined, in parallel, when discussing about scaffolding and tutoring in computer-mediated collaborative inquiry:

1. **The organizational level**, which means the initial “framing” or organizing the learning community’s activities, or structuring the task according to the pedagogical approach.
2. **The tool level**, which means built-in structures or software tools in the educational technology environments for structuring and directing students’ work (Reiser, 2002),

3. **The process level**, which involves coaching, situation-specific guidance, and expert participation during the inquiry process.

The combination of various approaches used in the present study provided new insights into the dimensions of scaffolding and tutor’s roles in the collaborative inquiry process. It is probably not possible to develop a general theory or model of scaffolding in collaborative inquiry, because the tutor’s role is dependent of the context and the pedagogical approach chosen. In any case, to examine the nature of scaffolding, especially, in computer-mediated collaborative inquiry, compared to more traditional educational settings, is valuable in developing the support and guidance for educators to assess and develop their own scaffolding practices in the context of CSCL.
References


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Table 1

Summary of the database material used in the study.

<table>
<thead>
<tr>
<th></th>
<th>Group 1</th>
<th>Group 2</th>
<th>Group 3</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of students&lt;sup&gt;a&lt;/sup&gt;</td>
<td>4</td>
<td>7</td>
<td>6</td>
<td>17</td>
</tr>
<tr>
<td>Discourse forums in FLE</td>
<td>5</td>
<td>4</td>
<td>5</td>
<td>14</td>
</tr>
<tr>
<td>Produced notes</td>
<td>56</td>
<td>87</td>
<td>95</td>
<td>238</td>
</tr>
<tr>
<td>Text pages in the data file&lt;sup&gt;b&lt;/sup&gt;</td>
<td>24</td>
<td>42</td>
<td>34</td>
<td>100</td>
</tr>
</tbody>
</table>

<sup>a</sup> Each group had also a tutor, and the knowledge produced by them is also counted in the numbers of the table.

<sup>b</sup>The number of text pages was counted from a file, which included all the database material accumulated to FLE of each groups’ discourse (writing times of notes, note headings, authors’ names, category of inquiry scaffolds chosen, and the text of each note).
Table 2

The mean number of posted notes, replies sent to other participants’ notes, replies received from others, and the number and length of the discourse threads in FLE in each study group

<table>
<thead>
<tr>
<th></th>
<th>Group 1</th>
<th>Group 2</th>
<th>Group 3</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Students’ notes</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. notes (M)</td>
<td>11.75</td>
<td>10.14</td>
<td>14.17</td>
</tr>
<tr>
<td>No. notes (Min / Max)</td>
<td>3 / 20</td>
<td>3 / 19</td>
<td>3 / 33</td>
</tr>
<tr>
<td>Sent replies (M)</td>
<td>5.25</td>
<td>5.29</td>
<td>8.83</td>
</tr>
<tr>
<td>Received replies (M)</td>
<td>6.75</td>
<td>7.00</td>
<td>8.17</td>
</tr>
<tr>
<td><strong>Tutors’ notes</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. notes</td>
<td>9</td>
<td>16</td>
<td>10</td>
</tr>
<tr>
<td>Proportion of group notes</td>
<td>16%</td>
<td>18%</td>
<td>11%</td>
</tr>
<tr>
<td>Sent replies</td>
<td>8</td>
<td>10</td>
<td>5</td>
</tr>
<tr>
<td>Received replies</td>
<td>2</td>
<td>4</td>
<td>9</td>
</tr>
<tr>
<td><strong>Discourse threads</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. threads</td>
<td>14</td>
<td>17</td>
<td>12</td>
</tr>
<tr>
<td>Length (M)</td>
<td>3.29</td>
<td>4.06</td>
<td>7.08</td>
</tr>
<tr>
<td>Length (Min / Max)</td>
<td>2 / 6</td>
<td>2 / 9</td>
<td>2 / 20</td>
</tr>
</tbody>
</table>
Table 3

Proportions of the built-in progressive inquiry scaffolds used by the tutors and the students to label their notes in FLE

<table>
<thead>
<tr>
<th>Inquiry scaffold</th>
<th>Tutors’ notes</th>
<th>Students’ notes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>f</td>
<td>%</td>
</tr>
<tr>
<td>Question</td>
<td>5</td>
<td>14.3</td>
</tr>
<tr>
<td>Working theory</td>
<td>1</td>
<td>2.9</td>
</tr>
<tr>
<td>Deepening knowledge</td>
<td>3</td>
<td>8.6</td>
</tr>
<tr>
<td>Comment</td>
<td>10</td>
<td>28.6</td>
</tr>
<tr>
<td>Metacomment</td>
<td>15</td>
<td>42.9</td>
</tr>
<tr>
<td>Summary</td>
<td>1</td>
<td>2.9</td>
</tr>
<tr>
<td>Total</td>
<td>35</td>
<td>100.0</td>
</tr>
</tbody>
</table>
Table 4

An example of the first three notes in a discourse tread of seven notes.

Problem 1999-03-25 13:08 Jaakko P.: Group’s communication
How does a group communicate? What proportion of working time goes into communication? Can the time be used more effectively?

Comment 1999-04-07 19:39 Satu T.: About communication
[A quote of the previous note]
I can’t say precisely which proportion of working time is spent in communication, but it is a lot. If a group has been formed to solve a problem shared by many fields, the group has most likely been assembled from experts in these various fields. In such a group, communication takes the biggest part of working time, since members of the group need to convey to others the viewpoint represented by their own field to the problem at hand, which can sometimes be very difficult because each field has its own terminology and problems. If the group is formed from experts in the same field, the professional terminology is common and the communication becomes easier, in which case it takes relatively less time compared to the previous heterogeneous group. The time needed for communication can certainly be decreased by various means. Personally, I’ve found so called face-to-face communication most efficient. In such a situation, the person at the receiving end can immediately ask questions, if she or he did not understand the issue. Gestures and different models can then be applied to explain the problem. In this way, the deliverer of the message can check if the information was getting through, and notice whether it was understood in every respect. Telephone and computer are still for the time being more limited communication tools, since expressions and gestures stay un-interpreted.

Comment 1999-04-19 14:05 Tutor 3: about the working environment
Presented: [A quote of previous notes]
While operating in this environment, face-to-face communication is not used. What is your opinion of the applicability of such computer-mediated environment (FLE) for collaborative knowledge building? (These issues you’ll need to consider, at the latest, as you are providing course feedback). From the perspective of the theories about communication, group work and shared cognition that you have provided: In your opinion, how well do the models of overcoming the limits of intelligent behavior come true while operating in this environment (you do not need to write about it, but think…)

…
Table 5
Proportions of the elements of scaffolding in the tutors’ notes based on the categorization of ideas

<table>
<thead>
<tr>
<th>Category of scaffolding</th>
<th>Tutor 1</th>
<th>Tutor 2</th>
<th>Tutor 3</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>f</td>
<td>%</td>
<td>f</td>
<td>%</td>
</tr>
<tr>
<td>Ask explanation-seeking question</td>
<td>9 †††</td>
<td>22.5</td>
<td>14 †</td>
<td>25.0</td>
</tr>
<tr>
<td>Produce expert's explanation</td>
<td>10</td>
<td>25.0</td>
<td>17</td>
<td>30.3</td>
</tr>
<tr>
<td>Review and evaluate the discourse</td>
<td>11</td>
<td>27.5</td>
<td>15</td>
<td>26.8</td>
</tr>
<tr>
<td>Recommend study practices</td>
<td>10</td>
<td>25.0</td>
<td>10</td>
<td>17.9</td>
</tr>
<tr>
<td>Total</td>
<td>40</td>
<td>100.0</td>
<td>56</td>
<td>100.0</td>
</tr>
</tbody>
</table>

Note. Significance tests are based on hyper-geometric probability estimations (see Bergman & El-Khoury, 1987).

* Observed frequency smaller than expected by chance alone (p < .05).

††† Observed frequency larger than expected by chance alone (p < .001).
Figure Captions

**Figure 1.** Elements of the pedagogical model of progressive inquiry.

**Figure 2.** Proportions of the elements of scaffolding in the tutors’ replied-to and not-replied-to notes.