

# Technology-Mediation and Tutoring: How Do They Shape Progressive Inquiry Discourse?

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In higher education, there is a challenge to gain the full benefit of the potentials of learning technology for collaborative knowledge advancement and for scaffolding practices of academic literacy and scientific argumentation. The technology, ideally, would be used to provide support that enables students to deal with more demanding tasks than they could otherwise handle.

We investigated the benefits of learning technology by examining the role of technology-mediation and tutoring in directing students' knowledge production in inquiry-based learning. A comparative analysis of inquiry discourse was conducted for 3 conditions between nonmediated and technology-mediated inquiry processes, the latter both tutored and nontutored. Qualitative content analysis was employed to examine how the scale of scaffolding related to the nature of knowledge produced. Furthermore, a descriptive analysis of the progression of discourse was conducted to examine evidence for deepening the question–explanation process, development of ideas in dialogue, and self-reflection.

The scaffolding provided by the learning technology (The Future Learning Environment), together with the possibility for dialogue, appear to have supported practices of problem-setting, self-reflection, and collaborative development of ideas. Students in the 2 technology-mediated conditions were developing their ideas in dialogue, building on each other's knowledge and questions. Tutoring was found to be valuable for providing additional models and tools for advancing inquiry. Specific to the students of the nontechnology condition (who wrote learning-logs) was that they put more effort into understanding the theoretical content, evaluating and arguing it, but they did not engage in shared development of ideas.

Through a combination of the practices, the authors foresee a potential, in higher education, for development of in-depth inquiry and practices of knowledge advancement including the nurturance of epistemic agency.

There have been many recent advances in collaborative technology that are proving to be of some value in education. Yet, one may inquire whether the design and application of the technology reflect the results of research into advanced practices of promoting and scaffolding higher level learning (Edelson, Gordin, & Pea, 1999; Pea et al., 1999; Scardamalia & Bereiter, 1994). Increasingly, the novel combinations of technological and pedagogical innovations challenge students and teachers to try new methods and adapt to new cultures of collaboration within networked environments. We educators should be cautious, however, about letting the current capacity and applications of learning technologies dictate all of the activities we plan for students. Further research and comparative analysis are still needed to identify productive combinations of technology-mediated collaboration and the practices of reading, writing, and self-reflection that lead to the development of scientific inquiry skills and academic literacy.

In higher education, computers and networks are utilized in a broad range of functions. Koschmann (1996) analyzed this variation in terms of the implicit theory of learning and of pedagogy reflected in these various paradigms. Largely due to the social and cultural practices and norms in education, a strong emphasis has lain in “instructional efficacy,” which is linked with a requirement to produce measurable and scalable learning outcomes generally evaluated in terms of content mastery. Moreover, it can be argued that the vast majority of teaching and studying in higher education is still organized according to the practices and epistemologies that have been described as the transmission model of instruction (Koschmann, 1996; Pea, 1996). This model depicts the student as the receiver and the teacher as the provider of the content in instruction.

If one asks a pedagogical expert or a learning researcher to define the ultimate goals of instruction, however, content mastery might fall somewhat behind other, more cumulative and comprehensive skills—more precisely, metaskills—and epistemological changes. Such goals would most likely include the development of self-regulative and metacognitive skills (cf. Boekaerts, Zeidner, & Pintrich, 1999); reflective and critical thinking skills (King & Kitchener, 1994; Kuhn, 1991); demonstrated academic literacy in reading and writing (e.g., Geisler, 1994; Wineburg, 1991); skills of collaboration and interaction (Brown & Campione, 1994); and developed epistemic agency, which paves the way for collective, knowledge-building efforts (Bereiter, 2002; Scardamalia & Bereiter, 1994, 2003). *Epistemic agency* means that the students themselves take responsibility for their own learning efforts and advancement of understanding. Furthermore, agency in one’s own learning is thought to provide a basis for sustained work to advance and elaborate ideas across situations and contexts (Paavola, Lipponen, & Hakkarainen, 2004; Scardamalia, 2002).

Moving toward these goals requires that the entire educational culture undergo substantial changes toward inquiry practices that support the evolution of the metaskills that we have mentioned. Next to content mastery, there should be a par-

allel emphasis on skills for solving complex tasks and engaging in collaborative inquiry, directly related to modern accounts of expertise and teamwork. This calls for pedagogical structures that direct students' efforts into taking responsibility for self-regulative processes that enhance commitment to inquiry and facilitate deepening their inquiry.

Scardamalia and Bereiter proposed that networked learning environments, when properly designed, help to facilitate epistemic agency by moving students' own ideas into the center of educational practice and providing a forum to participate in sociocultural activities of knowledge-building communities (Bereiter, 2002; Scardamalia, 1999). What characterizes successful knowledge-building communities is that they establish epistemic norms and values that all participants are aware of and work toward (Scardamalia & Bereiter, 2003; see also Olson, 2003).

Although epistemic norms emerge between people and are thus a collective accomplishment, the participants may appropriate these norms as regulatory principles of their own inquiry and activity. Rather than subsuming their thinking under the teachers' cognitive authority, students do well to take responsibility for their own thinking and problem solving. We propose that a principal goal of university education should be to encourage and facilitate emergence of such agency. It, in turn, is dependent on there being appropriate inquiry experiences, and these are necessarily constrained by existing educational practices.

In the literature on educational research, one finds several models for scaffolding the processes of inquiry in primary- and secondary-level education. A number of them have been developed to model and facilitate inquiry in natural sciences—for example, scientific visualization technologies to support inquiry-based learning in the geosciences (Edelson et al., 1999), project-based science and laboratory work (Krajcik, Blumenfeld, Marx, Bass, Fredricks, & Soloway, 1998), laws of force and motion (White & Frederiksen, 1998), and concepts of growth and development (Zuckerman, Chudinova, & Khavkin, 1998). It may be argued that an inquiry process in well-defined scientific fields takes different forms and calls for different scaffolding focuses than in ill-defined domains. In the former, the problem-setting, hypothesis testing, systematic data collection, and analysis practices demand more attention. In the latter, ill-defined quasi-scientific domains—such as social sciences or philosophy—efforts at theory building, conceptual clarification, argumentation, and critical evaluation are more often the focus of scaffolding.

In this study, the pedagogical model of progressive inquiry was applied to structure and model the inquiry practices in an ill-defined domain (psychology). The courses described in this study have been designed to enrich existing practices by modeling and bringing in elements of progressive inquiry into lecturing courses. The purpose of the research has been to examine the role of technology-mediation and tutoring in promoting (progressive) inquiry pedagogy in authentic university education.

## THE MODEL OF PROGRESSIVE INQUIRY

*Progressive inquiry* is a heuristic framework for structuring and supporting students' epistemological advancement and development of epistemic agency and related skills. The model of progressive inquiry has been developed by Hakkarainen and his colleagues (Hakkarainen, 1998; Hakkarainen, 2003b; Muukkonen, Hakkarainen, & Lakkala, 2004). It is primarily based on theories of knowledge building (Scardamalia & Bereiter, 1994), the interrogative model of scientific inquiry (see, e.g., Hakkarainen & Sintonen, 2002; Hintikka, 1999), and concepts of distributed expertise in a community of learners (Brown & Campione, 1994; Hakkarainen, Palonen, Paavola, & Lehtinen, 2004).

The progressive inquiry model shares with the knowledge-building approach an assumption that inquiry is seen as a process mediated by shared knowledge objects, such as questions, working theories, and explanations. These mediating artifacts bring "trialogical" elements into play that restructure the process of inquiry (Paavola et al., 2004). Trialogical is intended to denote not only dialogue between the participants, but a three-way interaction between the participants and their shared object of inquiry. The defining characteristic of progressive inquiry is, accordingly, the *object-orientedness of inquiry* (Engeström, 1987)—pursuit of advancing shared knowledge objects across situations—rather than a particular group working method (a lecture may serve progressive inquiry when it provides conceptual scaffolding for an agent's individual or collaborative inquiry process; Hakkarainen, Lonka, & Lipponen, 2004). The mediated nature of inquiry helps to distinguish knowledge building (i.e., advancement of collective knowledge) from mere learning (i.e., focused on change in an agent's mental representations; Bereiter, 2002).

The progressive inquiry model posits that, to arrive at a deeper understanding of phenomena and problems in an area of investigation, one has to take part in a deepening question–explanation process. Original, often vague questions are based on learners' initial understanding of the issues. Research in question-asking has provided evidence that generation of questions is triggered by clashes between world knowledge and the materials or stimulus at hand, such as contradictions, anomalous information, obstacles to goals, uncertainty, or obvious gaps in knowledge (summarized in Otero & Graesser, 2001). In the progressive inquiry process, the initial questions are generally found to be decomposable into several subordinate questions, which, in turn, become the focus of students' inquiry (Hakkarainen & Sintonen, 2002). Ideally, the original questions are answered in this progressive process, but it sometimes turns out that the initial questions are such that science, at present, is not able to answer them, but can only offer competing hypotheses or theories.

The progressive inquiry model specifies certain epistemologically essential elements that a learning community needs to go through, although the relative importance of these elements, their order, and actual contents may show great variation from one setting to another. The objective is not to follow the elements mechani-

cally, but to offer conceptual tools to discuss and make visible the strategies and activities that are crucial in knowledge-building efforts and inquiry practice. As depicted in Figure 1, the following elements have been placed in a cyclic but not step-wise process to describe the progressive inquiry process (see, e.g., Hakkarainen, 2003b; Muukkonen, Hakkarainen, & Lakkala, 1999).

### Distributed Expertise

Distributed expertise is a core characteristic of the progressive inquiry process, drawing attention to collaboration as a means to extend individual efforts and skills. The progressive inquiry model intends to engage the community in a shared process of knowledge advancement and to convey, simultaneously, the cognitive goals for collaboration. Diversity in expertise among participants and interaction with expert cultures promote knowledge advancement (Brown et al., 1993; Dunbar, 1995). Acting as a member in the community includes sharing cognitive responsibility for the success of inquiry. This responsibility can be explained in terms not only of deliv-

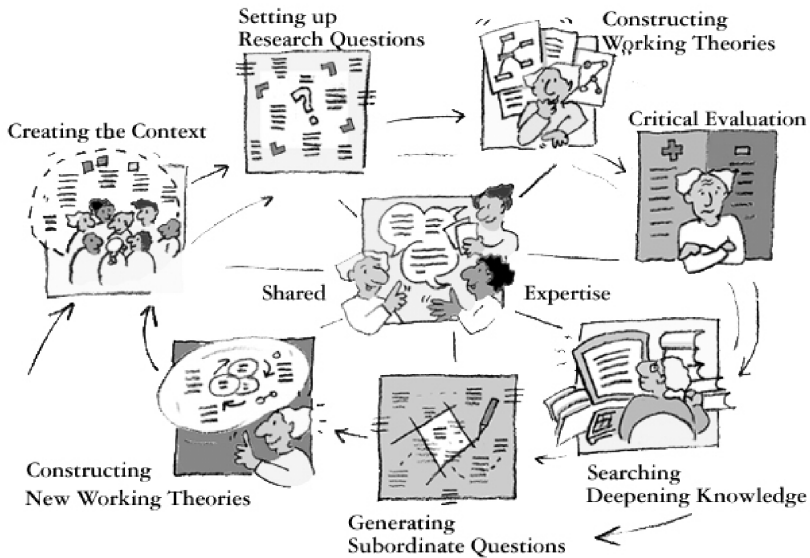


FIGURE 1 Elements of progressive inquiry. From *Online Collaborative Learning: Theory and Practice* (pp. 28–53), by H. Muukkonen, K. Hakkarainen, and M. Lakkala, 2004, Hershey, PA: Information Science Publishing. Copyright 2004 by Idea Group Inc. Reprinted with permission.

ering tasks or productions on time, but also of learners taking responsibility for discovering what needs to be known, goal setting, planning, and monitoring the inquiry process (Scardamalia, 2002). Salomon and Perkins (1998) argued for the importance of developing students' (and experts') social metacognition: students learning to understand the cognitive value of social collaboration and gaining the capacity to utilize socially distributed cognitive resources.

### Creating the Context

In the beginning of the process, the teacher or tutor creates, together with students, a context 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. It is important to create a social culture that supports collaborative sharing of knowledge and ideas that are in the process of being formulated and improved.

### Setting up Research Questions

An essential aspect of progressive inquiry is generating students' own problems and questions to direct the inquiry (Hakkarainen & Sintonen, 2002). Explanation-seeking questions (Why? How? What?) are especially valuable. The learning community should be encouraged to focus on questions that are knowledge driven and based on the results of students' own cognitive efforts and the need to understand (Bereiter, 2002; Scardamalia & Bereiter, 1994). It is crucial to see studying as a problem-solving process that includes addressing problems in understanding the theoretical constructs, methods, and practices of scientific culture.

### Constructing Working Theories

A critical condition for developing conceptual understanding is generation of students' own hypotheses, theories, or interpretations for the phenomena being investigated. In the beginning of the inquiry process, it is important that phenomena be explained with existing background knowledge before using information sources. This serves a number of goals: first, to make visible the prior (intuitive) conceptions of the issues at hand. Second, trying to explain to others is an effective way of testing the coherence of a student's own understanding, and it makes the gaps and contradictions in his or her own knowledge more apparent (e.g., Hatano & Inagaki, 1992; Perkins, Crismond, Simmons, & Under, 1995; Schank, 1986). Wells highlighted the role of others in one's learning: "by contributing to the joint meaning making with and for others, one also makes meaning for oneself, and in the process, extends one's own understanding" (Wells, 1999, p. 108). Third, it serves to create a culture in which knowledge is treated as essentially evolving objects and

artifacts that can be improved (Bereiter, 2002). Consequently, thoughts and ideas presented are not final and unchangeable, but rather utterances in an ongoing discourse (Wells, 1999).

### Critical Evaluation

Critical evaluation addresses the need to assess strengths and weaknesses of theories and explanations that are produced and to direct and regulate the community's joint cognitive efforts. It holds a constructive evaluation of the inquiry process itself, placing the process at the center of evaluation and not only in the end result. Again, rather than focusing on individual students' productions, it is more fruitful to evaluate the community's productions and efforts and give the student participants a main role in this evaluation process. Critical evaluation is a way of helping the community to rise above its earlier achievements by creating a higher level synthesis of the results of inquiry processes.

### Searching Deepening Knowledge

Looking for and working with explanatory scientific knowledge is necessary to deepen one's understanding (Chi, Bassok, Lewis, Reiman, & Glaser, 1989). A comparison between intuitive working theories and well-established scientific theories often discloses the weaknesses and limitations of the community's conceptions (Scardamalia & Bereiter, 1994). The teacher of a course must decide how much of the materials should be offered to the students and how much they should actually have to search out for themselves. Questions stemming from true wonderment on the part of the students can easily extend the scope of materials beyond what a teacher can foresee or provide suggestions for. On the other hand, searching for relevant materials provides an excellent opportunity for self-directed inquiry and hands-on practice in struggling to grasp the differences between various concepts and theories.

### Generating Subordinate Questions

The process of inquiry advances as learners transform the initial big and unspecified questions into subordinate, and frequently more specific, questions based on their evaluation of produced new knowledge. Formulation of subordinate questions helps to refocus the inquiry (Hakkarainen, 1998; Hakkarainen & Sintonen, 2002; Hintikka, 1999). Directing students toward returning to previously stated problems, making more subordinate questions, and answering them are ways to scaffold the inquiry.

## Developing New Working Theories

New questions and scientific knowledge that the participants attain give rise to new theories and explanations. The process includes publication of the summaries and conclusions of the community's inquiry. If all productions to the shared database in a collaborative environment have been meaningfully organized, all participants should have easy access to prior productions and theories, making the development of conceptions and artifacts a visible process.

The model of progressive inquiry may be mediated with the use of collaborative technology. In the following, we address the roles that technology-mediation and tutoring have been found to play, according to the research on collaborative technologies.

### ROLE OF COLLABORATIVE TECHNOLOGY

The use of collaborative technologies is associated with improved performance in a considerable number of studies (reviewed in Lehtinen, Hakkarainen, Lipponen, Rahikainen, & Muukkonen, 1999). These improvements spring from a collaborative community that provides multiple zones of proximal development (Brown & Campione, 1994; Vygotsky, 1978). Therefore, by drawing on a larger collective memory and the multiple ways in which knowledge can be structured among individuals working together, groups attain more success than individuals working alone (Bruer, 1993; Hakkarainen, Palonen, et al., 2004; Palincsar, 1998). Furthermore, when other students, tutors, teachers, or experts participate in an inquiry process, they demonstrate various forms of self-reflection, explications of understanding, engagement in problem-setting and redefinition. Such processes may serve as a model for less experienced students in their knowledge-building efforts.

An important means for developing epistemic and subject understanding is to use variation to create understanding (Marton & Booth, 1997). The variation in the ideas, concepts, and explanations offered by students in a learning community serves to bring attention to possible misunderstandings and gaps in knowledge and to create bridges between seemingly unlinked entities. This practice is naturally embedded in collaborative learning technology.

Research in learning technologies has focused attention on the functionality or scaffolding that can be embedded in the technology to support an inquiry process. As already pointed out by Vygotsky (1978), we humans use cultural—historically developed artifacts (signs and tools) to scaffold and to mediate our activities. A variety of scaffolding tools can be brought into operation through technology—for example, software structured so as to induce learners to categorize their contributions according to the essential aspects of inquiry (i.e., “thinking types”; Scardamalia & Bereiter, 1993). Some projects have focused on developing pieces



of software specializing in scaffolding specific learning processes, such as Knowledge Integration Environment and its argumentation tool SenseMaker (Davis & Linn, 2000). The main benefit of functionality and tools should be that they provide support that enables students to deal with more challenging tasks than they could otherwise handle (Reiser, 2002).

Recent research in higher education demonstrates a general agreement on the possibilities afforded by collaborative technologies—namely, through offering a basis for multiple perspectives and idea development, engaging participants in social interaction and dialogue, or supporting reflection and development of cognitive and metacognitive skills (see, e.g., Brandon & Hollingshead, 1999; Dysthe, 2002; Guzdial & Turns, 2000; Hara, Bonk, & Angeli, 2000). Utilizing and creating shared representations of complex issues is a means of enhancing sustained collaboration. Suthers and Hundhausen (2003) studied how external representations play an important role, for a group of learners, in their construction and manipulation of shared representations. They compared graphical, matrix, and textual representations and drew attention to the types of representational guidance that were manifest: initiation of the negotiation of meanings, provision of an external representation that can be referenced in negotiation, and supplying a foundation for implicit shared awareness (group memory). It appears to us that providing tools that allow participants to represent their knowledge and ideas invites them to engage in an extended dialogue with collectively accessible ideas rather than merely a dialogue between minds.

A number of studies have highlighted interrelated difficulties in adopting collaborative technology into educational practice. For instance, a review by Kreijns, Kischner, and Jochems (2003) addressed what they named the two main pitfalls of social interaction in collaborative learning environments: first, taking it for granted that participants will socially interact simply because it is possible, and second, neglecting social interaction and socioemotional processes because of sole focus on cognitive processes in instructional activities. Other studies (e.g., Guzdial & Turns, 2000; Hara et al., 2000; Hewitt & Teplov, 1999; Lahti, Seitamaa-Hakkarainen, & Hakkarainen, 2003) have reported problems with intensity of participation and the depth of engagement—for example, unevenness of participation, shortness of discourse threads, the teacher's overly important position in discourse, lack of reciprocity, or absence of a clear pedagogical perspective in the design of computer-mediated educational settings.

The research presented in this article has been motivated by prior research prominent in the computer-supported collaborative learning (CSCL) literature, which has repeatedly argued for the benefits of distributed expertise and collaborative knowledge building. Most of the reported research on inquiry learning, however, has taken place in primary or secondary education. Furthermore, it has often been difficult to distinguish the precise role of the technology-mediation, whether the results have been affected by exceptional efforts on the part of teachers or students or whether the results obtained in laboratory settings would be the same in

authentic university education. Hence, an open question remains of how the underlying processes of an inquiry quest in higher education may be best supported, including a deepening question–explanation process, development of ideas in dialogue, and self-reflection.

## ROLE OF TUTORING

Advanced technology can facilitate the students' collective inquiry effort, but does not, by itself, provide sufficient support without appropriate pedagogical arrangements and scaffolding of the collaborative learning endeavor (Lehtinen et al., 1999; Lipponen & Lallimo, 2004). Many studies have shown that inquiry is not easy for students and that they need considerable support (e.g., Krajcik, Blumenfeld, Marx, & Soloway, 2000; Winn, 2002). In addition to providing the students with the conceptual framework and structuring the tasks and activities according to the pedagogical approach, it is also necessary to provide students with coaching, situation-specific guidance, and expert participation during the inquiry process (Lakkala, Muukkonen, & Hakkarainen, 2005; Ligorio, Talamo, & Simons, 2002; Mercer & Fischer, 1993; Wells, 2000). The most important role of the teacher and the facilitators of collaboration is to create the context for this collaboration and provide anchors between the theoretical representations, world knowledge, and the real-life experiences that students report. It is also necessary to structure and scaffold the process and keep it active and in focus during the progression of the course.

## RESEARCH OBJECTIVES

In empirical research on collaboration, it is usually individually defined traits and outcomes that are measured and reported, and, as Barron (2003) suggested, this may be due to the “challenge of translating theoretical insights about system-level effects into reliable measures” (p. 46). It is a challenge that we have faced while conducting the empirical analysis reported here. We have adopted units of analysis that are not intended to provide for investigation of individual inputs into the inquiry (although they remain traceable to specific authors). Instead, the units are intended to allow portrayal of the collective efforts, at group level, to conduct inquiry.

Prior research has shown that inquiry is challenging for students and that, in many instances, the use of collaborative technology, despite its benefits, has been associated with great variation in the intensity and reciprocity of engagement. A large body of published empirical research has been framed by questions related to the use of technology; thus, it has focused attention on the functionality or scaffolding that can be embedded in the technology or provided evidence on the technical and social aspects of collaboration through learning technologies. Yet, mea-

sures of interaction or collaboration only partially answer questions about how to foster advancement of collective knowledge. More needs to be understood about the nature of knowledge and the processes undertaken in inquiry. From a pedagogical point of view, there is a further need for research to identify practices that promote sophisticated, deepening inquiry, anticipated in higher education.

The objective of this research is to explore pedagogical structures that direct students' efforts into taking responsibility for self-regulative processes that enhance commitment to inquiry and facilitate deepening their inquiry processes. We address the role of (a) technology-mediation and (b) tutoring in directing students' knowledge production in inquiry-based learning. The sophistication of inquiry is defined by using the model of progressive inquiry as a theoretical framework and evaluated from two observable characteristics: the nature of the produced knowledge and the evolution of the inquiry processes. For this purpose, three university course settings are examined to answer the following questions:

1. How is the scale of scaffolding (none, technology, and technology and tutoring) related to the nature of knowledge produced by students?
2. How does technology-mediation (compared to nonmediated) influence the progression of inquiry processes?
3. How does tutoring (compared to nontutored) contribute to the progression of technology-mediated inquiry?

The data have been drawn from two authentic university courses. The courses afforded us three conditions within similar instructional settings: first, students without technology mediation or tutoring; second, students with technology mediation and tutoring; and third, students with technology mediation but without tutoring. The latter two conditions were originally designed to investigate the uses of collaborative technology in university education, and the first condition provided us with data on a nonscaffolded inquiry within the same setting. We chose these three conditions for addressing our questions because they were judged to differ in respect of the scaffolding provided by the environment (possibility for dialogue, scaffolding tools) and the tutoring (expert modeling by human tutoring); hence, they were expected to create varying degrees of support for the inquiry process.

In the first phase of research, to find out how the scale of scaffolding may relate to the nature of produced knowledge, we employed qualitative content analysis to examine students' engagement in an inquiry process. We expected that the profiles of the conditions would reflect the scale of scaffolding provided and that more support would result in a more versatile discourse with attention to all aspects of the inquiry model. We also presumed that the combination of technology-mediation and tutoring (second condition) would be the most productive.

In the second phase, to answer our questions about how technology-mediation and tutoring contribute to inquiry processes, we turned our attention to the qualita-

tive differences in the progression of discourses: how deepening the question–explanation process, development of ideas in dialogue, and self-reflection were displayed in the inquiry processes. We expected that the first comparison between Conditions 1 (nontechnology) and 2 (tutored-technology) would indicate the effects of technology mediation by showing differences between facilitated inquiry without formal out-of-class activities versus inquiry with out-of-class knowledge building required and facilitated by software and tutors. Furthermore, the second comparison between Conditions 2 (tutored-technology) and 3 (nontutored-technology) would show the differences between progressive inquiry processes, which were both facilitated by knowledge-building software, but one with human facilitation and the other without it. This would inform us about the role human facilitation plays in promoting knowledge building and reflection in such an environment.

## RESEARCH DESIGN

The conditions examined were as follows: In the first condition (nontechnology), students took part in a lecture course without any organized collaborative use of learning technology. They produced learning-logs and essays individually and wrote comments to each other's learning-logs between the weekly lectures; they formed the *nontechnology* groups. The second and third conditions involved the Future Learning Environment (FLE), but in slightly different ways. In the second condition (tutored-technology), students took part in the same lecture course. Between the lectures, they collaborated in the Web-based, networked learning environment—FLE—and had tutors to facilitate their inquiry within that environment; these students were designated the *tutored-technology* groups. In the third condition (*nontutored-technology*), students took part in another lecture course with the same teacher and collaborated in the FLE, but did not have a tutor to facilitate their inquiry. The tutored and nontutored technology groups in the second and third condition are referred as the *technology groups* or the *two technology conditions*.

### Course Descriptions and Group Selection

The participants in the first two conditions were enrolled in a 15-week university course in cognitive psychology with weekly lectures (24 hr in total). Altogether, 80 students arrived for the course, representing multiple fields of study. These students were divided, according to their choice, into two conditions. In the first condition, the “nontechnology” one already mentioned, the students ( $N = 63$ ) did not use any groupware, but participated in the course in a more traditional format, following lectures and writing learning-logs on paper (printed with the computer or handwritten), on their own, between the lectures. They had been asked to pursue their inquiry process, write learning-logs, and read at least two logs produced by 2

fellow students in the same group and provide written feedback for them. The written commenting of learning-logs took place about halfway through the course, so that each student had at least two logs to read and comment and had at least two comments by different people on their own logs. The students were urged to collaborate with their group members to answer their common questions; however, no suggestions for how to do it were provided. They had also completed an essay-writing task at the end of the course.

Among 63 of these “nontechnology” students, we identified five groups who had completed the assignments, had taken part in the first lectures (hence, we expected them to be well acquainted with the progressive inquiry model and have taken part in designing research questions), and essentially, had commented on each other’s learning-logs. Setting these conditions for inclusion in the study provided us evidence that they had formed a group instead of working solo or in pairs. Furthermore, we randomly designated three of these groups (total of 17 students) as research participants; they constituted the three “nontechnology groups”—LLog-1, LLog-2, and LLog-3—with 5–6 master’s degree students in each group.

The participants of the second condition—17 students who had volunteered—started work with the FLE, forming three groups under the direction of tutors (“tutored-technology groups”—FLE-1, FLE-2, and FLE-3). These groups consisted of 4–7 master’s degree students who had attended the lectures and continued their inquiry with a tutor-facilitator participating in the networked environment. The requirement for course credit was to contribute by writing in a progressive inquiry process to FLE’s Knowledge Building (KB) environment. They were also expected to participate actively by reading, commenting on productions of other members of the group, and writing a summary of their own contributions and learning process at the end of the course.

In the third condition, the data were collected from all students—essentially volunteers—in a 9-week course (also 24 hr in total) in cognitive psychology, a course given by the same teacher, using the same pedagogical approach. The group, consisting of 13 students, had weekly face-to-face seminar meetings and no tutors to help in inquiry. For the course credit, it was required to read the study materials and actively participate in seminar sessions and knowledge building in the FLE. These students, as already stated, are the “nontutored-technology,” FLE-4 group.

The content and coverage difficulty of the two courses were very similar; the shorter course had the same amount of lecture hours in it, they were only held in a more intense period. All of the students were guided during the first two lectures in both courses to formulate research problems. Initially, they produced the research problems individually; they continued by discussing their research problems with a peer; and, finally, within a small group, they selected the most interesting questions to pursue. These questions were then presented to all of the participants during the lecture. After this initial problem-setting, the technology-groups were instructed to continue their inquiry processes between the weekly lectures in the

FLE, and the nontechnology groups were instructed to continue with the inquiry process in their own learning-logs. Overall, the evaluation criteria for all of the groups were similar; emphasis was given to demonstrating understanding of the theoretical concepts of the course as well as to explaining their knowledge of recent research on learning. Furthermore, they were asked to provide an account of their own learning process.

During the lectures, the progressive inquiry model was proposed as a framework for individual and collaborative inquiry. There was no attempt to organize specific activities around the model, but it served as an epistemological and metacognitive tool for participants. Throughout the courses, the teacher provided theoretical and scientific knowledge by lecturing, inviting questions and discussion, and making reference material available. The lectures were combined with lively conversations on the subjects at hand, but they were not recorded or documented in this study.

### Collaborative Environment

The tool used in the investigated courses—FLE—was an asynchronous groupware system developed by the Media Laboratory, University of Art and Design Helsinki, in collaboration with the Centre for Research on Networked Learning and Knowledge Building at the Department of Psychology, University of Helsinki. It is designed for supporting collaborative knowledge building and progressive inquiry in educational settings. The FLE is an open-source collaborative tool (<http://fle3.uiah.fi>; Muukkonen et al., 1999). The pedagogical model of progressive inquiry is embedded in the FLE design and functionality (Muukkonen et al., 1999). The KB module provides a shared space for working together for solving problems and developing ideas and thoughts generated by the participants. In KB module, the sent messages are organized in threads under the forums titled according to the starting problems of the course, decided by the teacher together with the participants. The messages are visible to all members in the same study group. In the investigated courses, for each group, one discourse forum was founded for the discussion of ways of working; other forums were created for chosen research problems. In the KB module, progressive inquiry is promoted by asking a user who is preparing a message to categorize the message by choosing a category of inquiry scaffold—in the same way as in a computer-supported intentional learning environment (Scardamalia & Bereiter, 1994)—corresponding to the basic elements of the progressive inquiry model (Problem, Working theory, Deepening knowledge, Comment, Metacomment, or Summary). These scaffolds are intended to help the students to move beyond simple question–answer discussion and elicit practices of progressive inquiry, by making the conceptual tools constantly available as new messages are constructed and later read. The use of the scaffolds was explained in the beginning of the courses.

## Participants

The participants in the first two conditions had a previous course in “Psychology of learning and thinking I” given by different teachers before enrolling for this course, “Psychology of learning and thinking II.” There were no statistical differences in the grades obtained from the prior course,  $t(28) = .46, p = .65$ , between students in the first condition, the nontechnology groups ( $M = 1.9, SD = .68$ ), and students in the second condition, the tutored-technology groups ( $M = 1.8, SD = 1.1$ ), where grades had been given between 1 (*satisfactory*) and 3 (*excellent*). The participants took part in this course to complete 2 credits of a 10-credit minor unit in psychology, which was offered to master’s degree students at the University of Helsinki. Therefore, their backgrounds were in many fields of study at the University of Helsinki, including forensics, mathematics, history, languages, and education.

Overall, the number of years that the students had studied varied from 0 to 6, although some of the students did not provide this information. In Finland, the average age of students starting their college- or university-level studies is rather high due to the entrance examination process, which selects a limited number of students for each discipline. The majority of students taking part in this course were female, which was reflected in the gender distribution of the groups (see Table 1). The students in the second condition were on average 2½ years younger ( $M = 24.2$ ) than the students in the first condition ( $M = 26.7$ ). Because the students had volunteered for the tutored-technology groups, we could not influence the age distribution.

The participants in the third condition—the nontutored-technology group—were mainly master’s degree students of media education, and their course was entitled “Perspectives of cognitive psychology on media education.” These students were on average older than the students in the other conditions ( $M = 33.4$ ); 6 of them were getting an update on new technology in media education after having previously completed their master’s degree studies (however, they were not engaged in

TABLE 1  
Age and Gender Distribution

Condition	Group	n	Male/Female	Age		Mean Year in Studies
				M	Min/Max	
1. Nontechnology	LLog-1	6	1/5	26.7	22/32	4th
	LLog-2	6	1/5	28.3	23/34	4th
	LLog-3	5	2/3	25.0	20/31	2nd
2. Technology, tutored	FLE-1	4	1/3	24.5	22/30	3rd
	FLE-2	7	2/5	23.2	21/25	3rd
	FLE-3	6	2/4	25.0	21/30	3rd
3. Technology, nontutored	FLE-4	13	7/6	33.4	24/43	—

Note. LLog = learning-log; FLE = Future Learning Environment.

postgraduate studies). Two of the students in this condition did not receive a final credit for this course because of their low activity. Unfortunately, we do not have information on the number of years studied for the participants in this condition.

### Methodological Limitations

Methodological limitations, hardly avoidable in real class situations, were presented by age differences and self-selection into the conditions. It cannot be excluded that self-selection to the conditions had some influence on their engagement. As observed from the level of their previous grades, however, the first (nontechnology) and second (tutored-technology) conditions did not differ in the level of their prior knowledge of the content. For the second comparison—the second (tutored) and the third (nontutored) conditions—it may be presumed that students did not differ in their technology skills and orientations because the students in the second condition volunteered to use technology, and the students in the third condition were directed toward technology by their field of study. With these limitations in mind, we conducted the statistical analysis at a group level to allow for variation within conditions to remain visible. Furthermore, the higher average age of the students in the third condition may have provided them with additional skills compared to younger students (especially compared to the second condition). There remained clear differences, however, in the progression of the discourse between the second, tutored, and the third, untutored condition, which suggests that the age difference had not benefitted the third condition considerably in a sense that the influence of tutoring would be exceeded.

### Data Sources and Analysis

The data analyzed in this study was composed of the learning-logs written by the students in the nontechnology groups in the first condition and the database discourse of the technology-mediated (FLE) groups of the second (tutored) and third (nontutored) conditions.

*Qualitative content analysis.* The purpose of the content analysis (see Chi, 1997) was to examine the type and quality of knowledge produced by the students according to a plausible operationalization of the progressive inquiry model.

An examination of the technology-mediated groups' productions indicated that their messages consisted of several ideas. As a first step, we segmented the messages into propositions, which were considered to address only one idea. The learning-logs were segmented following the same principle. To analyze the reliability of segmentation, an independent coder classified 5% of the messages and also 5% of the learning-logs. The intercoder reliability (single measure intraclass correlation; McGraw & Wong, 1996) was .90 for the learning-log segmentation, .88 for the



FLE-message in the second condition, and .87 for the FLE-messages in the third condition, which indicated that the reliability of segmentation was satisfactory.

As a second step, several rounds of category development were carried out, with the framework of progressive inquiry in the background. Mapping all of the elements suggested by the model did not fit with the data. Through a data-grounded approach, a connection was discovered for major underlying processes of the progressive inquiry model—that is, setting of research questions, constructing working theories, searching deepening knowledge, and critical evaluation. They were categorized as *Problems*, *Own explanations*, *Source-based explanations*, and *Metacomments*, respectively. In addition, the preliminary analyses revealed a need for two additional content categories. For the FLE data, we created a category, *Quote of another student's idea*, because there were segments in the messages that were direct quotations from other messages. For the learning-logs, another category code was necessary, which was labeled *Reference to lecture*. The coders had access to the technology-groups' students' coding categories (assigned as a student chose the category of inquiry scaffold for a message), as they were part of the analyzed texts. Each message typically had several segments in it, however, so the coding used for analysis was at a more detailed level.

In our content analysis, each segment or idea was classified to one of these six categories. All of the ideas fitted in these six categories of ideas, which were set up as mutually exclusive. Furthermore, to analyze the interrater agreement of classification, an independent rater classified approximately 10% of ideas produced in each condition; the Kappa coefficient for rater agreement was .88 (Cohen's Kappa) for the learning-logs, .83 for the FLE-messages in the second condition, and .87 for the FLE-messages in the third condition, which is indicative of a clearly stronger congruity than chance alone would produce. In the following, each idea category is described in more detail, and examples from one tutored-technology group (FLE-1) and one nontechnology group (LLog-1) are presented. The tutored-technology group is pondering the question, "What is the role of mental pictures in expert thinking?" A student in the nontechnology group is writing about intelligence and development of expertise.

1. The *problem* category referred to all questions produced by the students. These were sentences formulated as questions or asking a question.

FLE-1 (S1): *What kind of knowledge is better learned with the use of mental pictures?*

LLog-1 (S20): *Based on Sternberg's thoughts, should we say that all people are in principle mathematically "equally intelligent," but only a fraction is particularly interested in it and therefore develop their intelligence in that direction?*

2. The category of *own explanations* represented students' own ideas and thoughts, their own explanations for the problem being investigated, or generalizations of their experiences. These were coded as verbalizations of their own understanding, even if they resembled writings from their study materials, but did not provide a reference to an original writer or source.

FLE-1 (S1): *I agree, but I believe that in terms of mental pictures, people are facing the same cognitive problems as there are in general about the use of memory. The limitations are not in the storing capacity, but in the ability to retrieve the details stored in memory.*

LLog-1 (S20): *For students, especially in the beginning of their studies, many things are presented very black and white, and the students only pay attention to content space in their reading.*

3. The *source-based explanations* category represented the explanations that contained explicit reference to an article, book, or other study material on which the student had based the explanation. A reference to specific theory or model and a reference to results from research were also coded as source-based explanations, even if the source was not explicitly mentioned.

FLE-1 (S1): *In the same book by Turunen and Paakkola [...] this topic of scientific visualization is also discussed. According to the authors, by use of imagination we are able to connect and change the mental pictures collected in our brain. They claim that imagery is a special kind of activity of the mind.*

LLog-1 (S20): *In the field of social psychology, it has been noticed that, for example, the way of thinking typical for a society—western individualism and eastern collectivism—influence different thinking processes of an individual, such as attribution; whether a certain event is explained predominantly by external factors, related to the situation, or internal factors, related to personality.*

4. *Metacomments* were considered to consist of assessments of one's own learning process, assessment of own understanding, advancement of the discourse, functionality of the FLE-tools, or explanation of what would follow. Ideas were regarded as metacognitive when they contained an explicit expression of generalization from one's own or the group's experience, an evaluation of one's own thinking process (e.g., confusion), or a reflection on the learning process.

FLE-1 (S3): *This discussion has shown that we have clear conceptions of mental pictures and that we are interested in using them as tools for thinking.*

LLog-1 (S20): *As my studies progressed, I realized to my surprise that I had learned only one point of view or one theory on the subject, although there were many different and even contradictory views.*

5. A student was said to *quote another participant's idea* if he or she presented excerpts of that participant's earlier message within the one currently being posted. A quote contained the verbalizations of someone other than the author of the analyzed message. Therefore, it contained ideas that the author had chosen to highlight from previous messages. The entire quote was treated as one segment. Following the succession of ideas in quotes was beyond the scope of this research.

6. The category of *reference to lecture* was assigned when the segment placed its content to have been said or done during the lecture, serving often to set the context for the reader. These were most often events and activities that took place during the lecture.

LLog-1 (S20): *During the lecture, we talked about conceptual change and how rarely it takes place during studying.*

The content analysis was performed with the ATLAS.ti software. The coded ideas were then analyzed to obtain a comparative measure of the content of written productions. Cell-specific exact tests (Bergman & El-Khoury, 1987) were performed to examine whether the observed frequencies in each cell (or group) deviated from what could be expected by chance alone. Cell-specific exact tests assume that the observed frequency of a cell in a two-way contingency table follows a hypergeometric distribution. The test utilizes the total sample size to represent the population size, the row total to represent the sample size, and the column total to represent the number of objects in the population of this type for the analysis of whether a specific cell frequency is larger or smaller than what could be expected according to an independence model.

*Process analysis.* The results of the content analysis offer a good overview and quantitatively comparable information about the nature of students' knowledge productions in the three conditions. The frequency distributions do not enable, however, the examination of the changes in the knowledge production over time, differences in discourse patterns, or the role of individual ideas in broader context—in short, the evolution of the process. Therefore, in the second phase of data analysis, we used more descriptive methods to evaluate the differences in the nature and style of the knowledge production in the differing conditions. For this purpose, the unit of analysis was extended to cover the entire material for each group to enable a process perspective on the discourse. Two researchers read the data several times and formed their individual opinions of the data. After that, characteristic differences were jointly identified and contrasted through discus-

sions between the researchers. Consequently, the process analysis presents a synthesis of what were considered distinguishing features in the progressive inquiry processes in our data; these features were judged as representing plausible operationalizations of the following inquiry goals: deepening the question–explanation process, developing ideas in dialogue, and self-reflection. The following two comparisons are reported.

First, we investigated the productions in the first (nontechnology) and the second (tutored-technology) conditions, in which the students were in the same course. Distinctive differences were uncovered in their problem-setting and theory-building practices, dialogical nature of the idea development, and style of self-reflections. Second, we compared the inquiry discourse in the productions of the second (tutored-technology) and the third (nontutored-technology) condition, in which the networked learning environment and the teacher—but not the course—were the same. In this comparison, attention was directed to whether and how the inquiry process got deepened and the apparent role of tutoring in it.

## RESULTS

We first present the results of content analysis of the written productions. An overview describes the differences between the conditions as the entire set of data is examined. Second, results of a more descriptive analysis is presented to highlight the differences in the evolution of the discourse processes.

### Overview and Comparative Analysis of Progressive Inquiry Elements in Students' Productions

In the first condition (nontechnology), the 17 students wrote 72 learning-logs, including 1,893 ideas. Each student had written between 4 and 6 logs following the lectures that they had attended. Analysis of the content of the learning-logs showed a distribution of problems, own explanations, source-based explanations, and metacomments, which are displayed in Figure 2. The highest proportions of the ideas were coded as own explanations, with an average of 64.2%, problems presented 11.2%, source-based explanations presented 11.6%, metacomments presented 9.0%, and references to lecture presented an average of 4.0% of the total ideas produced by the students in the learning-log groups. In the first condition, none of the ideas was coded as a quote of another participant; rather, the students were making references to lectures.

In the second condition, 17 students in the tutored-technology groups posted 203 messages, which included 1,353 ideas. In addition, the three tutors posted 35 messages, and the lecturer posted 3–4 messages for each group to FLE's database, which represented the principal research problems of the group. Each question

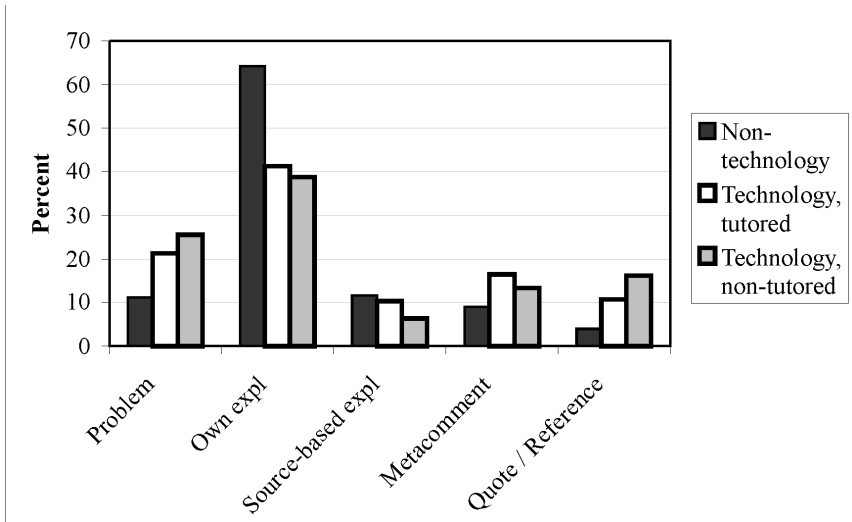


FIGURE 2 Relative proportion of categories of ideas by condition.

opened one knowledge building thread—for example, “How to become an expert in some field?,” “How to define intelligence and could it be measured?,” or “Importance of motivation in studies.” The students themselves decided which particular problems they would pursue. The messages by the tutors and the teacher were not included in the analysis. Analysis of the activity of these tutored-technology groups revealed a large variation in the number of postings to the FLE with the minimum of 3 messages and maximum of 33 messages ( $M = 11.9$  messages,  $SD = 8.8$ ) by a student. The highest proportion of the ideas was coded as own explanations, with an average of 41.2%, problems presented 21.3%, source-based explanations presented 10.3%, metacomments presented 16.5%, and quotes of another participant presented an average of 10.7% of all ideas.

In the third, the nontutored-technology condition, students posted 125 messages, which included 495 ideas. In addition, the teacher posted 9 messages to FLE’s database, which represented the principal research problems of the course, constructed collaboratively by students during the first lecture. Each research question opened one thread—for example, “How does the new information and communication technology support development of students’ expertise in different contexts?” or “What kind of new pedagogical problems may emerge in networked learning environments?” The students themselves decided which particular problems they would pursue. Apart from adding these principal research problems of the group into the database (as also in Condition 2), the teacher did not take part in the discussion being posted to the database, nor were the teacher’s messages included in the analysis. As in the second condition, analysis of the activity of the

nontutored-technology groups (the third condition) showed a large variation in the number of postings to the FLE, with the minimum of 1 message and maximum of 32 messages ( $M = 9.6$  messages,  $SD = 8.0$ ) by a student. The highest proportion of the ideas, again, were coded as own explanations, with an average of 38.8%, problems presented 25.5%, source-based explanations presented 6.3%, metacomments presented 13.3%, and quotes of another participant presented an average of 16.2% of the total ideas produced. Figure 2 summarizes the relative proportions of idea categories for each condition.

It was rather striking that the profiles of the two technology conditions resembled each other to a high degree, although it was the students in the first two conditions who actually participated in the same course and took part in the same lessons. The learning-logs condition was set apart particularly by a lower proportion of problems, a higher proportion of own explanations, and a lower proportion of metacomments and quotes/references.

The subsequent statistical analyses were carried out at the group level to allow the variation in the proportion of ideas between and within the conditions to remain explicit. A chi-square test performed on the number of ideas in each category revealed that there was a significant difference between the groups,  $\chi^2(24, N = 3741) = 480.5, p < .001$ . This led us to investigate further the differences between the three conditions at group level. Cell-specific exact tests were performed to examine whether the observed frequencies in each cell deviated from what could be expected by chance alone (see Table 2).

The results indicated that the learning-log groups appear to have produced a relatively larger number of own explanations, whereas there were relatively more

TABLE 2  
Frequencies for Categories of Ideas and Results of Cell-Specific Tests

Group	Idea Category					Total
	Problem	Own Explanation	Source-Based Explanation	Metacomment	Quote/Reference	
LLog-1	51 <sup>a</sup>	417 <sup>b</sup>	53	82	18 <sup>a</sup>	621
LLog-2	110 <sup>a</sup>	534 <sup>b</sup>	134 <sup>b</sup>	62 <sup>a</sup>	45 <sup>a</sup>	885
LLog-3	51	264 <sup>b</sup>	33	26 <sup>a</sup>	13 <sup>a</sup>	387
FLE-1	64	123 <sup>a</sup>	78 <sup>b</sup>	55	14	334
FLE-2	139 <sup>b</sup>	267 <sup>a</sup>	51	89	63	609
FLE-3	85	167 <sup>a</sup>	11 <sup>a</sup>	79 <sup>b</sup>	68 <sup>b</sup>	410
FLE-4	126 <sup>b</sup>	192 <sup>a</sup>	31 <sup>a</sup>	66	80 <sup>b</sup>	495
Total	626	1,964	391	459	301	3,741

Note. Significance tests are based on hypergeometric probability estimates (see Bergman & El-Khoury, 1987). LLog = learning-log; FLE = Future Learning Environment.

<sup>a</sup>Observed frequency smaller than expected ( $p < .001$ ). <sup>b</sup>Observed frequency larger than expected ( $p < .001$ ).

problems produced in the groups in the technology-mediated conditions. For source-based explanations, the results did not reveal consistent differences between the three conditions, but rather variation within the conditions. In the category of metacomments, there were relatively fewer metacomments in the productions of the nontechnology groups. Finally, in the quoting and referencing category, the two codes have been combined for the analysis to acquire an exhaustive comparison of the entire material, although they by nature represent two distinct practices. It was obvious, however, that within the technology-mediated groups there emerged a practice of shared development of ideas, which was lacking in the nontechnology groups' productions.

The subsequent analysis was intended to broaden the view of the inquiry processes by examining the qualitative differences between the conditions. First, we investigated the productions in the first (nontechnology) and the second (tutored-technology) conditions, in which the students were in the same course. Distinctive differences were uncovered in their problem-setting and theory-building practices, developing ideas in dialogue and self-reflection. Second, we compared the inquiry discourse in the productions of the second (tutored) and the third (nontutored) condition, in which the networked learning environment and the teacher—but not the course—were the same. In this comparison, the attention was directed to whether and how the inquiry process got deepened and what the role of tutoring in it was.

### Individual Learning-Logs Versus Technology-Mediated Discourse

Overall, the postings of the students in the technology groups were relatively short and condensed compared to the writings of the learning-log groups. The technology groups' writings often had the purpose of communicating a central idea to the knowledge-building process, but these messages often lacked precision or versatility in explanations. This multidimensionality of explanations was often constructed collaboratively, however, if the ideas were picked up by others in the group and further developed.

*Problem-setting and theory building.* In the second condition (tutored-technology), the messages posted by the students and tutors constituted several deepening interlinked threads, which extended over 15 weeks, so that the theories and problems were reformulated during the progression of the course. Within each of these tutored-technology groups, the students collaborated to gain better understanding of the main research questions. This became obvious by following the threads, but was also seen from their practice of quoting each other's ideas. They were commenting on each other's writings, asking for clarifications and explanations. Furthermore, the tutored-technology groups were, on average, more

often engaged in stating research problems and providing evaluations on the progression of their work (metacomments). The following problems are examples of how students were using the problems that they pursued to guide the discourse on the question, “What is the effect of motivation in regulation of studying?” The group had continued their discourse in 11 messages prior to these messages, and the tutor in the group has asked in a previous message to redefine the key problems in their discourse. In the following excerpts, 1 student (S15) has taken up that request and presented several messages to elaborate more detailed (subordinate) questions for their inquiry. Only the ideas coded as problems are presented in these excerpts. The discourse then continued following the lines suggested by these problem-setting messages.

FLE-3 (S15): *How is motivation born? ... To summarize this discussion, could we say that goals have an important effect [on] giving rise to motivation to study? ... If we pick the birth of motivation as one of our central problems, can we claim that goals strongly influence it?*

(S15): *How is motivation manifested? ... And how is motivation showing in our everyday life, e.g., behavior and thinking? Is motivation manifested also as a psycho-physiological phenomenon?*

(S15): *How can you influence motivation? ... As we were discussing [about] motivation for learning, it is naturally important to explain how motivation is created and how it is manifested, but I would say that probably the most important question is how can one influence it, that is how can a person direct one's actions in a certain direction?*

*The central issue here is that whether we see motivation for learning as a state that changes, meaning a state that can be affected, or is the starting point that it is a trait of a person, meaning that it should be trained especially in the different developmental stages in childhood. ... So, the problem: How can we influence motivation?*

The learning-logs of the nontechnology groups predominantly contained explanations of the students' own understanding and examples of their own experience with the theoretical issues presented during lectures. Overall, there were surprisingly few students who problematized the knowledge or the explanations that they were working on. The productions written by the learning-logs groups were focused on presenting the central theoretical content of the lecture and contained lengthy explanations of student's own experiences with the issues from the lecture, such as sharing of expertise or theories of intelligence. Their writings often referred to events and tasks during the lecture, which could not be found in the tech-



nology groups' postings. Nevertheless, several of these learning-logs could be described as providing an in-depth analysis of the main theoretical postulates and a personal perspective on the issues. The following is a part of a learning-log written after a lecture about distributed cognition.

LLog-2 (S26): *Learning-log, Distributed cognition*

*... During the lecture [there] developed a discussion about different orientations to learning, which were found to represent more some chosen strategies for functioning, instead of being controlling (permanent) trait (motivationally, avoidant or achievement oriented learner). Sometimes it could be meaningful to choose achievement-oriented motivation, so that understanding becomes a secondary goal after completing the course. People's time and interests are limited ... but I wonder whether it turns out that using very often the achievement-orientation actually impairs individual thinking skills?*

*I was also thinking about how conscious I am of the choices in strategies. Is for example the endless "leaving the essay writing to the last minute" a sign of avoidance or achievement orientation towards learning, or simply bad luck and even worse time-control? Engagement in progressive inquiry, which means that a motivated learner, who needs and wants deeper knowledge about her field, hardly gets enough external support in university (or work-life) and its productivity-pressured atmosphere, which has often been mentioned at lectures. Therefore, an individual's own commitment to learning, motivation and importance of social interaction are of high importance while aiming for in-depth learning.*

*Developing ideas in dialogue.* Another distinctive difference discovered in the comparison of the first (nontechnology) and second (tutored-technology) conditions was a different pattern of engagement in developing ideas in dialogue. It was intriguing to note that in all of the learning-logs, there were only a few occasions when a student commented on having received feedback from someone in the group; for example, a student explained that she was changing the structure of her learning-logs to include more theoretical considerations based on the feedback that she had received. In general, students in this condition did not refer to writings, feedback, or ideas presented by other students, although they met each other on the weekly lectures and got feedback comments at least twice during the course. The following is a written comment to a learning-log.

LLog-2 (S25): *Comment to learning-log*

*This learning-log is a clear overview, which covers the entire content of the lecture and includes references to [the author's] own thoughts and experiences. Thoughts have been verbalized with clarity and stiff scientific jargon has been avoided. Observations from events in real life and applications about different perspectives to intelligence created a joy in reading. Examples and discursive style in writing helped to describe the content and make it easily understandable. It was a fantastic idea to bring about creative intelligence at work by role-plays and games. Possible improvements: at times there is too much listing of things.*

Examination of these comments revealed that the nature of feedback was, in general, evaluative and did not reflect involvement in developing the ideas presented in the learning-logs. The comments to learning-logs appear to have concentrated on giving feedback on the writing style or ways to express and represent the content. In the technology-mediated discourse, this type of evaluative comment did not occur. Instead, the replies or comments concentrated on evaluating the collaborative process or, more frequently, built on the content-specific issues of the former messages—for example,

FLE-2 (S7): *Precisely! I have been wondering about the same thing. Since if the definition of intelligence changes by culture, situation, and the individual who is doing the measuring, ... , then how on earth is it possible to create something reliable and temporally relevant (I mean that everything evolves minute by minute and a measurement of intelligence should keep up to it)?!*

**Self-reflection.** A practice that evolved a great deal in the postings of the tutored-technology groups was self-reflection. The following is an excerpt from a summary on own learning process written at the end of the course.

FLE-2 (S5): *At the beginning of the course, my conception of intelligence was rather narrow. Although I saw that intelligence is not a static element, I still could not think of all of its components, or the more common factors that influence how people reason solutions. My initial conception was based heavily, on one hand, on some special cases where nature has made some restrictions, and on the other hand, on that intelligence is purely learned or acquired, and the wisest person is the one who has managed to read the most and use what they have learned. The possibilities that intelligence changes in time or that it may be difficult to define intelligence were not active in my mind. In addition, I formerly believed that*

*all existing qualities can be measured in some fashion. Now I'm not so sure of it.*

*My conception of intelligence has been swelling like dough. The bases for creating the conception have been things from lectures and the comments and contemplation in FLE, that I have either taken in or rejected as alien ways of thinking for myself. I have noticed that intelligence can be viewed from many perspectives and one can hardly find one satisfactory answer.*

*Before I explain my current conception of intelligence, I want to remind that this is how I think of it NOW. Over a week my thoughts can be radically different, since the process never results in something final, but conceptions change always with new knowledge and ideas. Here I have tried to create my own conception of it and at the same time criticize the limitations of my views.*

At first, the postings of the tutored-technology groups were written addressing the other participants in the group, showing that they were aware that others were reading their writings and engaging in a dialogue. As the course proceeded, another dimension was added to it, what could be characterized as *metareflection*—that is, addressing issues of the students' own understanding and explaining changes in their own thinking to others. Within the learning-logs, there were important self-reflections as well. However, their self-reflections were provided more often in a diary form and did not take the reader into consideration. The following is an example of a student writing in a learning-log.

LLog-3 (S34): *... I have started my studies at the university last fall. Now in the beginning it feels like studying at university is about balancing between collecting credits and the urge for deeper learning. Deeper and more extensive entities would demand more from the learners, but relatively they would also be more inspiring and rewarding. One could even get the feeling of knowing really something more about a topic and also of understanding its meaning personally.*

*At university, I would like to learn to become intelligent, but I don't really know what it is or can it be learned or taught! My problem is very fundamental, since if I'm not intelligent or cannot become so, then what am I doing here?*

### Tutored Versus Nontutored Technology-Mediated Inquiry

*Deepening of inquiry.* Although there were no clear differences between the two technology-mediated conditions according to the type of knowledge pro-

duced, based on the frequency results of the qualitative content analysis, examination of the productions following the discourse threads in the second (tutored) and third (nontutored) conditions drew our attention to another issue: It appeared truly challenging to get the inquiry to deepen in the sense that participants would not only provide their own opinions and explanations, but would actually start to look for materials, theories, and previous research on the questions that they were trying to answer. One indication of this challenge is that the proportion of source-based explanations in all of the students' writings was rather low. An excerpt from a discourse in the third (nontutored) condition provides an example of this. Here, the students were engaged in a dialogue to answer the question, "What kind of guidance is needed in technology-supported learning environments?"

FLE-4 (S43): *Most likely it should be even more sensitive. I mean by sensitivity that it is important to know the students (is it possible?) and secondly that each phase of the learning process is carefully analyzed and acted upon accordingly. The role, or rather the style, should be at different times initiating, supporting, challenging, evaluating, developing, etc. A facilitator's role includes along the content-specific aspects also the technical aspects, which in practice would translate to patience (our course gives an example of that), flexibility, time!, etc.*

(S43): *The first things that come to mind about the new problems are the ones about motivation and commitment. How to get students to participate and how to make the content and activity so tempting that at least a sprouting motivation would be directed on that key content or action. Interaction is one of the most central elements of networked-learning and commitment to it probably helps. Creating/forming trusting and open relationships is another challenge. How to achieve this; speaking the same language, internalizing the equal starting point of the situation, or something else? I approach here the discussion on the roles of a teacher and a tutor and especially the skills of tuning the emphasis between roles and actions.*

(S39): *Does the role of guidance change in a virtual learning environment (of which there are several kinds)? If it does, then why? If studying and learning occur principally in a technology-supported environment then one needs from guidance some sort of personal touch because otherwise it may be very difficult to get contact. I think this is linked to the quality of guidance since knowing how to guide and guiding skillfully are different things. I agree with [S43] that in a virtual environment one needs to know the students ... another matter is that how it is done; virtually or*

*in face-to-face meetings. Whether one is in the role of guiding (teacher) tutor, mentor or something else is an interesting question in my opinion. Or do we have a new name for a “virtual tutor?”*

- (S37): *[S39] wrote: [quoting the previous message] What would be the real advantage of knowing the students? In news groups and other electronic forums the people having discussions may “know” each other well although they have never physically met. So how does a virtual learning environment differ so critically in this matter?*

This interesting dialogue between 4 students continued in three direct follow-up messages in similar style involving 2 more students. Here, the discourse was sustained and on topic (cf. Guzdial & Turns, 2000), but clearly there was an element lacking: None of the students was bringing in any research results, concepts, models, or theories from literature. During their seminar meetings, there were vivid discussions of theoretical issues, but that discussion was not reintroduced in the learning environment. Here, we discovered the most significant difference between the tutored and nontutored conditions in our data. After a discourse thread beginning in a way that much resembled the previously cited discourse, the tutors in the second condition reminded the students to bring in the theories and research findings, for example, in the following ways.

- FLE-2 (T2): *The teacher sent a while ago some materials, which were dealing with the same issues as in this research question. Have you read the texts and what kind of thoughts did it give you?*
- FLE-3 (T3): *A good opening from an important topic. It’s quite easy to take for granted that a well-motivated person accomplishes better learning results than a non-motivated person. Could you explain in more detail why it is so? (what are the psychological explanations for this phenomenon)*  
*Further, what do you mean by developing the motivation that stems from a learner’s tendencies? How, by which means, and is it possible?*

Although these questions did not always have an impact, they did on several occasions change the discourse and scaffold it toward an iterative inquiry process, which was lacking in the third condition. The postings of the groups in the second (tutored-technology) condition displayed a process of returning to earlier questions, ideas, and theories and re-evaluating and reformulating them. It can be described as a more focused problem-setting tendency: Instead of opening up new lines of questions, the tutored groups were more often presenting subordinate

questions to previous ones. This excerpt is an example of a student making a summary of the inquiry process and explaining versions of theories that he had constructed during the course.

FLE-3 (S13): *The topic of the discussion was the limits of intelligent behavior and surpassing them. I tried first to define the problem-field by asking what defines the limits to intelligent actions. During the discussion it became apparent that everyone thought that the limitations originated in the limitations set by human brains, such as short-term memory or ability to retrieve from long-term memory. Nobody offered thinking methods as a solution, but concentrated on increasing the resources. In this discussion I defined intelligent behavior as problem-solving, particularly conceptually difficult and complex problems, which are very hard or impossible for a single individual. During the process I developed three versions of the theory.*

*Version 1, February 22nd: Human intelligent behavior is limited by memory and thinking abilities. With current technology it's not possible to improve the physical properties of the brain. Memory and thinking can be supported by external additional memory, e.g., blackboard and methods for modeling complex problems.*

*Version 2, March 25th: The limits of human intelligent behavior can be circumvented by forming a group of several people, who all concentrate on solving the same problem.*

*Version 3, April 26th: After reading the chapters sent by our teacher [...] I ended up combining my previous theories: The limitations of human intelligent behavior can be circumvented by physically distributed cognition, where humans share the cognitive burden with different tools they use, and by socially distributed cognition, where a group of people concentrates on solving the same problem.*

## DISCUSSION

The objective of this research was to explore pedagogical structures that direct students' efforts into taking responsibility for self-regulative processes that enhance commitment to inquiry and facilitate deepening their inquiry processes. It must be noted that, in our analysis, we have captured only a small part of the inquiry processes: the written productions in the learning-logs or in the Web-based environment. These writing contexts, by their nature, engage students in different writing practices. Nevertheless, these productions have enabled us to describe and to re-

flect on differences enhanced by technology-mediation and tutoring in authentic course settings.

### Relation Between the Scale of Scaffolding and the Nature of Knowledge

A qualitative content analysis was conducted to find out about how the scale of scaffolding (none, technology, technology and tutoring) related to the nature of knowledge produced by students. As stated earlier, we expected that the discourse profiles of the conditions would reflect the scale of scaffolding provided and that more support would result in more versatile discourse with attention to all aspects of the inquiry model.

Reviewing the results, the scale of scaffolding was found partly to relate to the nature of knowledge produced; scaffolding by technology appears to have supported the practices of problem-setting and metareflection. These are decisive elements for establishing a question–explanation process and evaluating efforts in its advancement. On the other hand, technology-mediation did not particularly encourage the students to plunge into the theories that they were studying. Concerning all conditions, we had expected to discover more focus on presenting and debating the theoretical content of the courses in an academic style. The need for such a focus has hardly been addressed in the CSCL literature. Further emphasis should be given to scaffolding practices of academic literacy, including exploitation and evaluation of knowledge sources.

Examination of the results of the content analysis revealed that the profiles of the technology-mediated conditions, tutored and nontutored, were surprisingly similar. Our immersion in the data, however, had led us to suspect that the level of analysis may not have reached qualities related to the process and its depth. Therefore, we undertook a more descriptive examination of the progression of discourses. We addressed the issues of the role of technology-mediation and tutoring in fostering practices of deepening the question–explanation process, developing ideas in dialogue, and self-reflection.

### Influence of Technology Mediation on Inquiry Process

To answer our question of how technology-mediation influences inquiry processes, we carried out a descriptive comparison between Conditions 1 (nontechnology) and 2 (tutored-technology), which suggested that technology-mediation with tutoring had supported the practices of stating research problems, evaluating the progression of inquiry, and metareflection. It appears also to have fostered a practice of developing ideas in dialogue, which was not observable in the nontechnology groups' writings. On the other hand, the nontechnology

groups concentrated relatively more on understanding and presenting the theoretical content of the course.

The influence of technology-mediation may be considered to consist of affordances of technology (e.g., Sullivan & Czigler, 2002) and consequences of its use. In our study, technology afforded a shared space for collaboration and provided embedded scaffolding for engaging in an inquiry process. The result, as suggested, was that the problem-setting and metareflection aspects of inquiry were facilitated. Technology also turned attention to collective efforts by helping to establish practices of monitoring joint advancement and building on each other's ideas. By contrast, in the inquiry processes of the learning-log (nontechnology) groups that we examined, no evidence for the practice of building on each other's ideas was found, despite the commenting process carried out. This apparent lack suggests that the nontechnology groups in our study did not engage in productive collaboration nor adequately exploit their distributed expertise. It seems likely that they interpreted the assignments as individual processes because collaboration tasks were not explicitly formulated. We believe that a more frequent commenting process might have resulted in more dialogue in the nontechnology groups.

### Tutoring in Technology-Mediated Inquiry

Finally, we examined the question, how does tutoring contribute to the progression of technology-mediated inquiry? In the second comparison between Conditions 2 (tutored-technology) and 3 (nontutored-technology), we investigated the role of tutoring in promoting knowledge building and reflection in such an environment. We found evidence that tutoring had some role (which might have been stronger) in scaffolding the students toward an iterative and deepening inquiry process. In practice, tutors were guiding the students to return to earlier questions, ideas, and theories and to readdress them. As evidence for the tutors' role, the process analysis recovered a more focused problem-setting tendency in tutored groups: Instead of opening up new lines of questions, the tutored groups were more likely to present subordinate questions to previous ones.

Having learned from our experiences, we acknowledge that the tutoring setup had not been created for optimal efficacy: The tutors were never face to face with the students, nor did they follow the lectures. In hindsight, it would likely have been easier to provide guidance had the tutors been more aware of what took place during the lectures. At the time, they could only build on what was going on in the database discourse. Having face-to-face contact might also have better supported the social aspects of collaboration.

### Developing the Progressive Inquiry Framework

In light of developing epistemic agency, the progressive inquiry model appears to have provided a heuristic framework for the students to engage in a predominantly



self-directed question–explanation process. A further question for research would be to examine the group-level processes and identify metadiscourse reflecting individual and group-level agency and, furthermore, their interplay and reciprocal development. This would call for operationalization of the concept of epistemic agency in more distinct terms.

An issue for the further development of applications of the progressive inquiry model is reflected in an impression of this investigators: There was an intriguing difference between the conditions in respect of mediated, object-oriented inquiry. Students who commented on their fellow students' learning-logs appeared to evaluate, from an external perspective, the quality of the other student's inquiry as a whole—without engaging in dialogue with the ideas articulated. They commented on ready-made contributions without extending the ideas involved or continuing the line of inquiry in question. The participants of the two other conditions, in contrast, appeared to engage in dialogue with ideas developed by their fellow students. Thus, there is suggestive evidence that the previous implementation of the progressive inquiry model, in an environment of technological support, apparently helped to bring about a process that was trialogical in nature through involving extended discussion with shared ideas (conceptual artefacts; cf. Paavola et al., 2004).

## EDUCATIONAL IMPLICATIONS

The results of the study by no means provide definitive answers to the question of how to foster advancement of collective knowledge in higher education. Four contributing factors are highlighted, however: First, providing an explicit pedagogical framework, the progressive inquiry model appears to have presented heuristic guidance for inquiry. Second, based on the evidence, technology-mediation provided additional tools for engagement in collaborative inquiry. Third, we consider that expert facilitation should aim more consciously at modeling deepening question–explanation processes. Fourth, what now seems compelling to examine is to what extent—and in what manner—an artifact, with joint investment, promotes extended dialogue and knowledge building. More efforts are still required to discover productive combinations of technology-mediated collaboration, involving collectively created artifacts and scaffolding for scientific practices of reading, writing, and self-reflection. Based on our current understanding, the following issues merit additional attention in teaching.

### Deepening the Inquiry

Overall, it appeared truly challenging for all students to deepen their inquiry: Participants should not only provide their own opinions and explanations, but actually start to look for and employ the materials, theories, and previous research on the

questions that they are trying to answer. Partly, it is a question of appropriate facilitation and modeling. Simultaneously, it is also a challenge for the use of learning technology in higher education because as long as collaborative technology is only used for discussing—sharing information on—important issues, it still does not yield the full benefit of its potential for knowledge advancement and inaugurate practices of academic literacy and scientific argumentation.

### Tutoring

Teachers or tutors in an inquiry process should be in charge of the organization of the entire process without taking the cognitive responsibility away from the students. A study by Lakkala and her colleagues (Lakkala et al., 2005) pointed out the difficulties in balancing tutoring engagement in their analysis of the scaffolding practices of the three tutors of our study; they concluded that the tutors were manifesting scaffolding practices that ranged from those of a traditional tutor who still controls the process to those of an inquiry-oriented tutor who seeks to promote advancement of the students' own metacognitive skills and knowledge-building practices. Scardamalia (2002) further emphasized that the teacher or tutor should explicitly aim at coaching the students gradually to take on themselves the responsibility for higher level aspects of inquiry and fostering the development of students' metacognitive competencies. Tutoring should provide additional models and tools for advancing inquiry—that is, asking for clarifications, focusing on looking for answers to own research problems, returning to earlier questions and theories, and re-evaluating and reformulating them with the support of knowledge sources.

### Individual and Collective Accountability

An inquiry process benefits from a shared representation that is the “object” of collaborative knowledge building. This may be a design or a report that represents the work of the participants or take the form of representational guidance as discussed by Suthers and Hundhausen (2003). It should reflect both individual and collaborative efforts. This investigation indicated that students representing the learning-log condition developed their own object of activity, but did not share it with their fellow students. Students working in the other two conditions, in contrast, developed a shared object of activity—the discourse within the database. Although the results of the study are encouraging, it appears that investigators would do well to highlight, simultaneously, both collective and individual responsibility and accountability (Olson, 2003). The latter emphasis is needed because cultural knowledge and learning become transformed to individual competence only through an individual participant's own extended efforts (Hakkarainen, 2003a). It appears to be essential to ask participants of university-level courses to both engage in intensive progressive inquiry efforts as well as produce an end report synthesizing re-

sults of their investigation; this procedure may ensure that each participant engages in both personal and collective inquiry.

### Institutional-Level Perspective

A vital and complex issue is the organization of the study and teaching practices as well as institutional-level settings in a form that supports long-term inquiry processes. Fjuk and Ludvigsen (2001) as well as Muukkonen and colleagues (Muukkonen et al., 2004) argued that investigators should consider whether curriculum design and the settings of courses are such that learners find it to be cognitively economical to undertake a deepening search for understanding. For instance, in the Finnish higher education system, students take about eight courses with equally numerous topics within a semester, even at the graduate level. This obviously limits the time available per course, and in-depth inquiry into one field calls for a special commitment, perhaps at the expense of other courses. Therefore, as Fjuk and Ludvigsen also pointed out, to change the educational settings, it is necessary to develop awareness of the contradictions and possible conflicts between pedagogical, institutional, and individual goals and practices. It is not enough to focus on changing one course at a time; rather, the challenge is in developing curricula that support students in acquiring deep understanding in their area and anchoring the scientific problems that they are studying to authentic problems of the various professional fields (Muukkonen et al., 2004).

Organizing every course as an inquiry process may not be feasible, but there are elements that may be implemented in any context. For instance, we recommend posing research questions prior to engaging in a search for materials in any situation as a means to stimulate curiosity and promote engagement in looking for answers to one's own questions.

As such, any single course is only a minor part in a developmental process. We argue that the development of epistemic agency and academic literacy are transformations that should take place throughout university education. Explicitly stating such goals for education could prompt educators and students alike to evaluate their role in every course side by side with content mastery. It is through repeated engagements that self-regulatory and metaskills, scientific argumentation, and practices of knowledge creation are learned, as in any sustained development of expert competencies and skills. Whether this can be accomplished depends on the structures of educational activities in which students take part across their academic studies.

### ACKNOWLEDGMENTS

Hanni Muukkonen's work has been supported by personal grants (2000, 2003) from the Finnish Cultural Foundation.

We are grateful to Hal White and Markku Niemivirta for helpful comments on earlier drafts of this article.

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