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Exploring metaskills of knowledge-creating inquiry in higher education

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Abstract The skills of knowledge-creating inquiry are explored as a challenge for higher education. The knowledge-creation approach to learning provides a theoretical tool for addressing them: In addition to the individual and social aspects in regulation of inquiry, the knowledge-creation approach focuses on aspects related to advancing shared objects of inquiry. The development of corresponding metaskills is suggested as an important long-term goal for higher education; these pertain, simultaneously to the individual, collective, and object-oriented aspects of monitoring inquiry. Taking part in collaborative inquiry toward advancing a shared knowledge object is foreseen as a means to facilitate the development of metaskills; the present study examines one undergraduate university course in psychology with that aim. The data consisted of a database discourse and students' self-reflections after the course, examined by qualitative content analysis. Three analyses investigated discourse evolution, knowledge advancement, and the challenge of the inquiry practices. The student-groups differed markedly in their engagement in the inquiry efforts. The study gave insights concerning novel challenges evoked by knowledge-creating inquiry, relating in particular to commitment, epistemic involvement, dealing with confusion, and the iterative nature of knowledge advancement. We propose the following implication for educational practices: Although dealing with uncertainty and areas beyond one's expertise, as well as engaging in self-directed collaborative inquiry, may seem overly demanding for students, such experiences are decisive for developing one's skills in dealing with open-ended knowledge objects in a longer time frame.

Keywords Inquiry learning · Knowledge-creation · Higher education · Metaskills · Progressive inquiry model · Trialogical learning framework · Collaborative learning · Episemetic objects

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Introduction

There is a proposal by Hakkarainen and colleagues to move from the cognitive (individualistic) and social (participatory) approaches to learning toward an inclusive knowledge-creation approach (Hakkarainen et al. 2004). This knowledge-creation approach addresses the question of how people learn to develop new artefacts and products or ways of working collaboratively over longer periods of time. In workplace contexts, this question is gaining increasing attention, but it is also a relevant question for higher education. It is generally agreed that workers in the knowledge society need competencies in knowledge creation and engagement in advancing shared objects (Bereiter 2002; Hakkarainen et al. 2004).

Yet, studies of student learning in higher education often point to the lack of skills for solving complex problems or ill-defined questions (e.g., Mandl et al. 1996), the effective pursuit of which, we hold, demands attention to such objects.

As higher education has a central position in educating knowledge workers, it is of interest that organizational studies have focused on the collective nature of work on epistemic objects (e.g., Miettinen and Virkkunen 2005) and, particularly, on the increasing importance of open-ended objects in expert work (Knorr-Cetina 1997). The quality of *open-endedness* means that objects (and knowledge) are not fixed, but the work is oriented to something that does not exist yet or is unknown. The term *epistemic object* (knowledge object) suggests a theoretical or conceptual dimension, and is somewhat broader than the subsumed concept of "knowledge artefact."

Looking at how this open-endedness or ill-defined quality of epistemic objects is realized in practices in higher education results in a remarkable polarization: On one hand, it is perfectly in line with the core activity in universities, namely, research, but it is, on the other hand, quite distant from the core educational practices of courses and exams, at least in undergraduate education. In this paper, the multiple demands for skills of knowledge-creating inquiry are addressed, both theoretically and empirically, as a challenge for higher education.

Theoretically, we draw upon the concepts of trialogical learning (Paavola et al. 2004). The *trialogical learning framework* upholds the cognitive (individualistic) or social (participatory) forms of expertise and learning (Sfard 1998), but emphasizes the *knowledge-creation approach* to learning. It highlights those kinds of activities where people collaboratively develop new artefacts, practices, and products or commit themselves to long-term processes of working and learning (Paavola et al. 2004; Hakkarainen et al. 2004). The knowledge-creation approach to learning applies ideas of object-orientedness and artefact-mediated practices from activity theory in order to build a framework where collaborative object-oriented inquiry is emphasized as a potential design principle of educational practice (Paavola and Hakkarainen 2005). The presence of these artefacts, practices, and products—"objects"—is the rationale for the term trialogic as contrasted with dialogic. Examples of such objects are theories, plans, protocol procedures, design drawings, prototypes, and collective practices.

In this paper, we have selected to use the term collaborative, knowledge-creating inquiry: It builds on the educational paradigm of inquiry learning and presents knowledge creation as a particular type of ill-defined inquiry process. Shared objects have a central position in knowledge-creating inquiry because (a) they are used to negotiate the objectives of collaboration (what are we trying to create? what will be the tangible outcomes of our collaboration?); (b) they embody a series of question-explanation processes (e.g., in a discussion forum); (c) they are based on iterations and revisions to the products (e.g., in report versions); (d) they require practical decisions about how to organize the collaboration and coauthoring process; and (e) once completed, the knowledge objects are conceptual artefacts available for further use. Other objects, artefacts, and tools may be shared among

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the participants, and, thus, function as boundary objects; however, they are not co-constructed, which we consider a central property of a shared object.

Empirically, we propose and investigate a continuum of three encompassing aspects of inquiry—individual, collaborative, and object-oriented. We argue that all these aspects need particular monitoring and regulatory attention from the participants as individuals and as members of a learning community. Learning to master these connected aspects gives rise to what we call *metaskills of collaborative knowledge-creating inquiry* (Muukkonen et al. 2009), although we acknowledge that using the notion "meta" is in some ways problematic. The problem of defining them as "metaskills" as compared to "skills" raises, for example, the issue of whether they are context-bound or general skills. We propose that these metaskills address the competencies required in practices of collective, object-oriented, and prolonged inquiry efforts, which are not reducible to an individual's activities or productions. In a sense, these skills are cultivated in practices where students are responsible for coordinating and directing their activities over the various aspects of inquiry: their own individual efforts, effective collaboration in group, and the progression and high quality of the knowledge objects they are developing. Although the timescale for developing such presumed skills may be relatively long, several years before full articulation, we suggest that learning experiences from individual courses can cumulatively contribute to their development, and, hence, provide justification for exploring them by means of a case study.

Research objectives

The promotion of object-oriented inquiry in higher education is a component of our quest to immerse students in authentic practices because that is where their skills are put to test upon graduation. To consider authentic practices in higher education necessitates some reflection on the included *knowledge practices* and how the latter are to be defined. Schatzki proposed that we view practices as "embodied, materially mediated arrays of human activity centrally organized around shared practical understanding" (Schatzki 2000, p. 2). What is central to our present argument is that Schatzki emphasizes that activity is dependent on "shared skills and understandings" for advancing common objects. A practice, according to Scribner and Cole (1981), can be unfolded in terms of three components: technology, knowledge, and skills. Practice refers to "a recurrent, goal-directed sequence of activities using a particular technology and a particular system of knowledge" (Scribner and Cole 1981, p. 236). Important for our present purposes, they use the term "skills" to ascribe the coordinated sets of actions involved in applying this knowledge in particular settings. Furthermore, Hakkarainen (this issue), argues that to nurture pedagogical innovations involving knowledge creation, one needs to explore locally cultivated knowledge practices and to identify the mechanisms which channel the participants' intellectual efforts in a way that elicits collective advancement of knowledge, which implies development of the relevant objects. In this paper, we present an account of knowledge practices aimed at collaborative knowledge-creating inquiry and focus on the skills aspect of practices.

The first goal of the research relates to exploring collective regulation of inquiry and its facilitation as a part of *authentic practices*. A great majority of studies on regulation of inquiry take place in controlled settings within short time spans (see Lin et al. 2005). This is understandable because otherwise it would be extremely difficult to capture elusive and relational executive processes regarding collective inquiry in an experimental design. Although experimental investigations are needed, the present investigators seek to investigate

indications of naturally occurring regulative processes, directed towards individual, collective, and object-oriented undertakings.

The second goal relates to the fact that previous research on metacognitive regulation of learning (e.g., Boekarts et al. 2000; Efklides 2006; Jost et al. 1998; Salonen et al. 2005) is highly focused on the individual actor's processes or working with a peer, but is less articulate about the work toward and through *shared objects* while students are engaged in an open-ended task. To examine the role of shared objects, we use the database materials to provide a description of working practices on shared knowledge artefacts. Further, we recognize a lack of research directed to understanding how students themselves perceive their commitment and ability to take part in collaborative knowledge creation. We expect that it would involve perceiving the value in committing to work on shared objects and engaging in building on each other's ideas. Therefore, we will address this question from two angles: how the database materials portray the inquiry practices and how the participating students reflect on them.

We begin in the next section by presenting prior research on skills concerning these three aspects of inquiry: individual, collaborative, and object-oriented. In practice, these aspects are systemically interacting, which renders efforts to clearly delineate the research background very challenging. Further, the research traditions addressing them have evolved rather disconnectedly, and used markedly different foci of analysis, varying between an individual, a group, a collective object, learning outcomes, or combinations of them. Our solution here is to take an analytic focus, which considers these three aspects as intertwined. This makes it necessary to introduce a number of concepts used in different traditions and to make links between them. Our aim, however, is to take collaborative knowledge creation as a starting point and to probe each of these three aspects in the theoretical background section. Following that, we will present data and analysis of a course in higher education. In conclusion, we shall return to the framing of metaskills for collaborative knowledge-creating inquiry and discuss the educational implications.

Skills concerning individual inquiry

Metacognitive and self-regulatory skills

In efforts to understand what kinds of skills are required for self-managing an individual's inquiry, one naturally turns to the theories of *metacognition* and *self-regulated learning*. At a general level, there exists an agreement that self-regulation of learning is an active, constructive process whereby learners set goals for their learning and engage in efforts in understanding, planning, monitoring, regulating, and reflecting on their cognition, motivation, behavior, and context (e.g., Boekarts et al. 2000; Järvelä et al. 2009; Quintana et al. 2005). Further, metacognition may be addressed as knowledge, experiences, and skills of monitoring one's own inquiry efforts (Efklides 2006). As Zimmerman and Tsikalas (2005) have emphasized, the key to evolving metacognitive capabilities is linking forethought, performance, and self-reflective phases of a learning process in such a way that the learners experience positive cognitive, motivational, and behavioral consequences of their efforts, which promote their feelings of competence and control.

Although self-regulation research has traditionally taken an individual perspective, recent research has introduced the concept of social metacognition, which deals with the meta-level processes related to interactions with peers as a distinct dimension of

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metacognition (e.g., Jost et al. 1998; Salonen et al. 2005). Jost et al. (1998) have argued that social metacognition may encompass skills for such central interpersonal processes as perspective taking, empathy, and effective communication, which require judgments about the knowledge, viewpoints, and understandings of other people. Here, we treat such skills as pertaining principally to an individual's self-monitoring, although they can be also perceived as a dimension of monitoring collaboration.

Cognitive research on teaching thinking skills has revealed that it is extremely difficult to teach *general thinking skills* separately from the development of domain-specific structures of knowledge (e.g., Perkins 1993). Rather, the ability to develop content-specific knowledge and apply it in situations frequently coevolves with the development of general thinking skills and metacognitive strategies (Davidson and Sternberg 1998). Perkins (1993) has, further, emphasized the importance of individual cognition in distributed cognitive processes because *epistemological knowledge* (such as knowledge concerning strategies of inquiry, patterns of explanation, and forms of justification) cannot become distributed because it is continuously needed by each individual for executing complex processes of inquiry.

Agency

The socio-cognitive research tradition has emphasized that an individual's inquiry is in many ways influenced and shaped by social practices. Particularly, learning is a by-product of taking part in social practice: It is not reducible to beliefs or other individual mental processes (Marton and Trigwell 2000). A member of a community may take a proactive role, which is to say, exhibit *agency*. Bandura (2001) has emphasized intentionality and individual and collective efficacy in the regulation of actions; Edwards (2005) has highlighted the need for relational agency as a capacity for working with others; and Virkkunen (2006) has stressed the hybrid quality of agency as agents are involved in long-term collaboration in different activity systems with partially overlapping objects of activity. Further, the notion of epistemic agency was introduced by Scardamalia (2002) and Bereiter (2002) in their investigations of the advancement of conceptual knowledge in a knowledge-building community. *Epistemic agency* becomes overt in situations where a student starts to consider how to advance one's own knowledge by reflecting, with others, on ideas and cultural knowledge on everyday phenomena. Further, it entails shifting away from teacher-directed activities and individual knowledge advancement towards community knowledge and a standpoint emphasizing the improvability of ideas (Bielaszyk and Blake 2006; Scardamalia 2002). We, here, link systematic improvements of ideas with furtherance and development of the objects of inquiry.

Prior research on agency has, thus, already moved us away from the emphasis on an individual's activities, and placed an individual actor's meta-level processes within the collective process and working on shared objects. This is how we suggest that the metaskills are distinct from metacognition: Agency and metacognitive knowledge and skills are fundamental factors in the engagement of any one participant; yet the complexity of an open-ended epistemic object and the mutual dependency between the participants adds new elements to the regulation and evaluation process. As knowledge-creating inquiry is strongly influenced by what the co-inquirers are doing and the epistemic goals set by the (educational) environment, it is consequently beyond any one participant's ability to fully control it. Thus, it appears that particular skills are needed for taking part in the collaborative activity and transforming the uncertainty into plans of advancement.

Skills related to collaborative aspects of inquiry

Collaborative aspects of inquiry is a general notion employed here to examine skills concerning intersubjective aspects of inquiry. There exists a substantial body of research on technology-enhanced collaboration within which small group interaction has been examined. In the context of higher education, several lines of investigation have shed light on the motivational processes (e.g., Järvelä et al. 2008), scaffolding of interaction and learning by providing scripts for collaboration (e.g., Weinberger et al. 2005), the influence of pedagogical design on the deepening of academic inquiry (e.g., Lakkala et al. 2008; Muukkonen et al. 2005), and argumentation and dialogic thinking as a means to capitalize on the multiplicity of perspectives to create new understanding (e.g., Andriessen 2006; Schwarz and de Groot 2007; Wegerif 2006). Prior research publications related to the skills for participating in such collaborative activities are reviewed in the subsequent sections.

Coordination and social awareness

Researchers have been interested in how to identify those factors in a collaboration process which are central to its success. Addressing the quality of collaboration, Meier et al. (2007) have proposed the following factors: communication to sustain mutual understanding and dialogue; joint information processing and reaching consensus; coordination involving task division, time management, and technical coordination; reciprocity of interaction; and motivation monitoring. Similarly, other researchers have examined challenges related to the creation of a joint problem-solving space; *coordination* of attention at the level of managing one's own efforts and trying to understand what others are doing simultaneously (Barron 2003; Mäkitalo et al. 2005). The success of collaboration may be hindered by the lack of *awareness* of other team members' working processes. Understanding which others are active, where they are working, what they are working on, and providing a team with an explicit model for collaboration have been emphasized as critical factors in raising the awareness of collaboration in a team (Gutwin and Greenberger 2004; Leinonen et al. 2005).

Cannon-Bowers and colleagues (Cannon-Bowers et al. 1995) have suggested that team members should have both generic and specific team competencies, consisting of knowledge, skills, and attitudes. For instance, generic competencies may relate to interpersonal skills or attitudes toward teamwork; individuals take these competencies across situations. On the other hand, specific team competencies relate to their knowledge of the other team members, their attitudes and knowledge, based on prior collaboration activities. These specific team competencies need to be readjusted following every change in team composition.

Contributing in a dialogical space

It has been proposed that collaborative inquiry is based on a "dialectical relationship and complementary functions of engaging in a back-and-forth dialogue with one's peers and reflectively reorganizing that dialogue into a monologic text for public presentation" (Enyedy and Hoadley 2006, p. 414). We agree, further, that it is crucial that engagement in knowledge advancement should have a transactive quality; self-disclosing important ideas, attracting peer attention to a new idea, and exhibiting continued development or challenging argumentation (Goos et al. 2002). The monological presentation of one's own ideas and explanations, for example, in texts, sketches, or designs, gives ideas an objective form and makes them available for others to reflect upon. Using collaborative

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technology opens the dialogical space to the entire learning community. A large body of research in the computer-supported collaborative learning (CSCL) approach focuses on the analysis of interaction patterns, argumentation, negotiation, or meaning making in discussion forums. Investigators have sought to understand the functioning of social communities and the practices and tools for cultivating exchanges and shared interpretations. Yet, epistemic objects tend to be slighted or ignored: There is still not sufficient understanding of the activities and related competencies regarding the advancement of them. Therefore, in the next section, we focus on the third aspect of metaskills of inquiry, the object-oriented inquiry activities.

Skills concerning object-oriented inquiry

Some investigators have emphasized that inquiry should have a pronounced focus on the shared advancement of conceptual ideas by iteratively editing, rewriting, or versioning the productions to demonstrate and explicate them (Bereiter 2002; Paavola and Hakkarainen 2005). This focus is proposed as a characteristic of the practice of continued development of epistemic objects, a process central to the knowledge-creation approach to learning. These objects, as we have stated, include theories, ideas, protocols, frameworks, and analyses of specific phenomena. Such a focus gives rise to a question not often examined in depth by the research reported regarding higher education contexts of collaborative learning: What is the role of the shared epistemic objects in the inquiry activity?

Specific to our reasoning about the object-orientedness of inquiry is that we locate it in a question-explanation process. The set of posed questions frames a possible series of concrete knowledge objects; these are introduced, perhaps in sketchy form, by the questioner, but then creatively added to and modified by inquirers trying to find answers to these questions in the course of inquiry.

Do knowledge-creation practices, therefore, require some additional skills from the students compared to individual inquiry or participating in social interaction? The study by Muukkonen et al. (2005) suggests that going deeper in an inquiry process was, indeed, a demanding endeavor for university students. The concept of "deepening" refers to characteristic events in the course of which learners not only provide their own opinions and explanations in the shared discourse, but actually start to look for and employ the materials, theories, and previous research on the questions they are trying to answer. Simultaneously, the collective advancement of ideas should become visible by means of sharing everything with others and transforming the initial knowledge productions through collaboration by rewriting and versioning the drafts. Such practice has been more common in studies in the field of design, where the conceptual and visual representations are used as a basis (by experts) for collaboratively evaluating and questioning design proposals and creating new ideas (e.g., Lahti 2007). Further, in order to encourage students to become aware of the multidisciplinary character of design practices (e.g., Seitamaa-Hakkarainen et al. 2005), the design task or problem itself should be open-ended and authentic.

In our inspection of prior research on how to describe the skills for advancing a shared object, we discovered critical subcomponents of general skill in object-oriented activities. First, the role of the shared knowledge objects is articulated in "knowledge building" theory (Bereiter 2002), which has brought to the fore the notion of the *collective development of conceptual artefacts*, and has influentially argued for the change in educational culture toward knowledge-building practices. Scardamalia (2002) has also emphasized the importance of collective cognitive responsibility, which relates to a *collective commitment*

to advancing the shared objects. Yet, their work has not explicitly addressed the skills present in or needed for such practices. Secondly, boundary-crossing competence (Walker and Nocon 2007) has been examined as the *ability to manage and integrate multiple, divergent discourses and practices across social boundaries*. People have a specific role as cultural brokers while tools may serve as boundary objects. Although this could be interpreted as relating to the intersubjective aspects of inquiry, it concomitantly directs the attention and the activities on a shared object. In the work of Walker and Nocon (2007), as well as in Tuomi-Gröhn and Engeström (2003), the ability to transfer between contexts is addressed as a specific competence. Boundary-crossing competence is enacted by *adapting knowledge from different areas of expertise and using the arising contradictions* (Engeström 1987) *as opportunities for creativity*. Further, this would suggest, in light of the skills for monitoring the evolution of objects of activity, that the ability to deal with constraints and obstacles is critical; one should be able to identify what disturbs the intended actions, define the conflicting goals that the individuals or the collective hold, and devise strategies and actions for overcoming them. Finally, Dym and colleagues (Dym et al. 2005) have highlighted a particular set of skills required in authentic inquiry situations; those dealing with the *ability to tolerate ambiguity, handle uncertainty, and maintain the big picture in sight* as central in a complex design process.

It is clear that such skills are nurtured neither by individual engagement in inquiry nor by collaborative interaction without a pronounced focus on developing a shared knowledge object. To become an expert in socially negotiated knowledge advancement, one needs to nourish skills beyond individual inquiry and collaboration. We will next present research on a case in order to reflect on practice-bound skills—or metaskills—for monitoring and engaging in object-oriented inquiry.

Research questions

The present investigation addresses the following questions:

1) How do the students engage in collaborative inquiry on an authentic task?
2) How do the students evaluate the process themselves?
3) How do the observed activities of student-groups and their self-reflections on the process relate to each other?
4) What are the indications of developing skills that deal particularly with engagement in the object-oriented aspects of inquiry?

Methods

The present research is in a succession to three prior courses using the pedagogical model of Progressive Inquiry with a Web-based collaboration environment (see Lakkala et al. 2008) as a means to educate students through inquiry practices. As such, it is an example of design-based research (e.g., Brown 1992; Collins et al. 2004). Design-based research is characterized as simultaneously and iteratively pursuing the goals of developing learning environments based on theories of learning, and using such environments as natural laboratories to study learning and teaching (Sandoval and Bell 2004). Naturalistic settings are accompanied by certain weaknesses when compared to experimental research designs: Noncontrolled designs and data can only partially reproduce the complexities of a long-term

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learning process. Employing students' self-reflections is another source of bias, but it also provides a perspective on the learning process not attainable by other means. Altogether, drawing upon these complexities of natural settings appears to provide insights for understanding some of the difficulties that students experience in adapting to new learning practices.

The pedagogical model of progressive inquiry

The investigated course was organized following the elements of the progressive inquiry model. The *Progressive Inquiry model* (Hakkarainen 2003; Muukkonen et al. 2005) provides heuristic guidance for engagement in a deepening question-explanation process. The basic assumption is that students and teachers take part in collaborative inquiry into an open-ended task. The elements in inquiry that the model emphasizes are the following: using the distributed expertise of participants in the learning community; creating the context of collaboration; setting up the initial research question; constructing working theories based on prior knowledge; and critically evaluating strengths, weaknesses, and gaps in current theories and explanations. Further, processes include searching deepening knowledge; developing subordinate questions framing the inquiry efforts; and developing new working theories to demonstrate evolving knowledge and understanding. The defining characteristic of progressive inquiry is, accordingly, the pursuit of advancing shared knowledge objects across situations—rather than a particular method of group working.

Course setting

The course was a two-credit undergraduate course, which lasted for a period of 11 weeks. Thirteen students participated in the course, "Psychology of modern learning environments," consisting of seven seminar meetings (3-4 h each) and collaboration within the educational software, the Future Learning Environment (FLE3), between the meetings. The seminar meetings were organized so that the first 2 h were spent with computers, and the following two as face-to-face discussion. The course setting was designed to place the cognitive responsibility for the advancement of inquiry largely in the hands of the students, although the process was closely monitored by a group of three tutors.

The first seminar meeting involved context creation by introducing the goals and themes of the course and explaining the progressive inquiry framework and how it would be used as a heuristic model to structure the inquiry process. In addition, only one of the seminar meetings was conducted in the form of expert lecturing, the rest were facilitated group work and discussion. Usually at least two tutors participated in each meeting. The first task of the students was to introduce themselves online. Following that, the FLE3 environment was used to highlight, cyclically, the elements of the progressive inquiry process by asking students to post research questions, state their own working theories, process evaluations, search relevant materials, and produce iterations of their final seminar papers. Each tutor had a main facilitator's role for one group; however, all participants could take part in any group's discourse in FLE. The students were provided with a great many recommendations and links to knowledge sources.

The research questions presented by students during the first sessions formed three themes for collaborative inquiry. These student-generated themes were: "Qualities of networked environments that support collaborative learning" in Group A; "Creative process in a networked community" in Group B; and "Teachers' and learners' roles in a collaborative networked environment" in Group C. Before the last meeting, in which the whole process

was evaluated together, the groups were guided to post the final version of their joint report to FLE3, and peers were encouraged to read and comment on them. After the course, the students wrote self-reflections of their participation in the course.

Participants

During the course, the 13 students formed three groups: Group A had originally four students (two female); their average age was 24 years, and they had studied on average 2.33 years. One male student dropped out in the beginning phase; he did not contribute to the inquiry. Group B had five students (three female); their average age was 23.6 and years studied, 3.6. The four students in Group C (three female) were on average older, 24.8 years, and they had studied the longest, 5 years on average (although the rise in the study-years was largely due to one ninth year student). The students came from several departments at the University of Helsinki; therefore, their backgrounds were in many domains, including chemistry, esthetics, technology, philosophy, and education.

Collaborative web-based environment

The technological environment used in the investigated course, Future Learning Environment (FLE3), was an asynchronous groupware system (v.3) 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 environment is an open-source collaborative tool (http://fle3.uiah.fi). The pedagogical model of progressive inquiry is embedded in the FLE design and functionality (Muukkonen et al. 1999). The Knowledge Building (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 (defined by the participants). The messages are visible to all course members. In the KB module, progressive inquiry is promoted by asking a user to categorize a message by choosing an inquiry scaffold (Problem, My explanation, Scientific explanation, Comment, and Evaluation of the process). The built-in scaffolds include tips for selection criteria, for instance, with My explanation: "Are you presenting your own thinking (notion, hypothesis, theory, explanation or interpretation)? Don't finalize your explanation. Post more elaborated versions later. If you have knowledge from an information source, you should write a Scientific explanation." 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 scaffolds was explained for the students in the beginning of the course.

Data-collection

The data of the present study consisted of database materials and students' self-reflections. The database discourse was examined to gain an understanding of the evolution of the inquiry process and engagement in developing the shared objects. The self-reflections were collected in order to gain personal, in-depth self-accounts of the inquiry process and the challenges related to knowledge-creating inquiry. They were considered to provide complementary perspectives on the process.

With the database materials, we narrowed the analysis to the three groups' discourse forums in FLE3; there the actual inquiry process took place during a period of 8 weeks, framed by the research questions. Final reports produced by the three student groups were used as complementary material. Several less central forums in the course database were excluded from the analysis: practicing the use of the environment, introductions, course information, and initial development of research problems, materials, and references.

At the end of the course, the students were asked to answer four open-ended reflective questions that were sent to them by e-mail; all students responded to these self-reflections. The questions asked were: 1) How do you evaluate your participation in the knowledge-building process. For example, where did you succeed well, what kinds of problems did you have? What did you get out of the knowledge building? 2) Would you have needed more tutoring and in what phases? 3) How do you compare studying during this course to some other more traditional seminars (or small group work)? 4) Other comments?

Data analysis

The content analysis of the data was carried out in two discrete processes. First, the database discourse materials were examined to construct a process view of the inquiry regarding the discourse evolution and the knowledge advancement. Second, the self-reflections were categorized to examine the students' perspectives on the monitoring of individual, collective, and object-oriented aspects of inquiry as well as the tools and course design. An overview of the data analysis and category development is presented in Table 1.

First, a categorization of the *discourse evolution* was developed by adapting the coding scheme used by Muukkonen et al. (2005) where categories were based on the major underlying elements of the progressive inquiry model (Problem, Own explanation, Source-based explanation, Metacomment, Quote of another student's idea, and Reference to lecture). In developing the categorization further, we noticed that university students generally tended to provide very complex explanations as their own ideas. It appeared that it would not do justice to their thoughts to call them just "own explanations"; these thoughts often had been cultivated through extensive knowledge-seeking activities, although students did not make reference to the sources of their knowledge. More importantly, they could make an advancement in inquiry in many complementary forms, that is, by posing questions, presenting own understanding, introducing new concepts or theoretical content, synthesizing or organizing the process. However, we have differentiated between categories "Explicative knowledge" which refers to explanations in their own words and "Theoretical knowledge," in which academic practices of introducing concepts and referencing literature are employed to explicate advances in inquiry. In addition, "Question," "Metaknowledge," and "Organize" categories were developed (see Appendix A: The examples have been translated from Finnish and shortened for conciseness without altering their meaning).

For the purpose of depicting the discourse evolution, a message was considered a suitably large unit of analysis. Each message was categorized as containing content predominantly in one of the discourse evolution categories. However, as some of the message contained elements from several categories, the selection was made by considering its key content and the Inquiry-scaffold chosen by the student, that is, considering the student's intended input into the inquiry process. To analyze the inter-rater agreement of classification, an independent rater classified approximately 10% of discourse messages; the Kappa coefficient (Cohen's Kappa) for rater agreement was .81, which was considered satisfactory.

The second analysis extended the analysis of the inquiry practices by investigating the *knowledge advancement* in the database discourse. The concept definitions and the versioning

Table 1 Overview of data analysis

Analysis	Focus	Categories	Data
Discourse evolution	Knowledge-creating inquiry practices	Question	Database
		Explicative knowledge	
		Theoretical knowledge	
		Metaknowledge	
		Organize	
Knowledge advancement	Shared objects	Concept definition	Database
		Report version	
Challenge of inquiry practices	Monitoring individual aspects of inquiry	Individual commitment	Self-reflections
		Individual knowledge advancement	
		Individual guidance	
	Monitoring collective aspects of inquiry	Collective commitment	
		Collective knowledge advancement	
		Collective guidance	
	Monitoring object-oriented aspects of inquiry	Individual knowledge advancement[a]	
		Collective knowledge advancement[a]	
		Collective guidance[a]	
	Reflection on tools and course design	Course evaluation	

[a] Relates to two aspects of monitoring inquiry

of the final report were treated as the central knowledge objects iterated in the inquiry, because they were the main outcomes of the students' shared knowledge advancement efforts. Based on a systematic examination of the discourse messages, occurrences of content items—which were either Concept definitions or Report versions (preliminary or final version of the final report)—were counted in each of the threads in the FLE environment. In the case of the final report versions, we consider this count only suggestive, because some of the versions may have been circulated by other means, such as e-mail.

Finally, the students' answers to the self-reflection questions were examined to gain an understanding on how the students perceived the *challenge of the inquiry practices* introduced in the course. The students particularly reflected on issues of individual and collective commitment, individual and collective knowledge advancement process, what kind of guidance they would have required both individually and collectively, and their overall evaluations of the course (see Appendix B for definitions and examples of the categories). All of the responses to the open-ended questions were included in the analysis; in the data, several reflections provided an evaluation of the course and the tool used, therefore, a category for course evaluation was also included.

The responses to the open-ended questionnaire were segmented into ideas; each idea addressed content in only one of the mutually exclusive categories. To analyze the inter-rater agreement of classification, an independent rater classified approximately 30% of self-reflection responses; the Kappa coefficient (Cohen's Kappa) for rater agreement was .83 for self-reflections, which was considered satisfactory.

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Throughout the results section, extracts from the database discourse and the self-reflections are used to highlight descriptive instances addressed in the findings.

Results

Technology-mediated discourse

The overall number of messages and documents posted to the FLE3 Knowledge Building forums and Webtops is presented in Table 2. Students wrote 76% of all messages and 69% of all documents in the database.

To answer the first research question, "How do the students engage in collaborative inquiry on an authentic task?" a content analysis was carried out on the three forums (65% of all messages). In Table 3 is presented an overview of database discourse in each group, based on the categorization of the message contents. In each group, there were several discourse threads in the forum, each represented as its own row in the table. The order of the threads follows the timeline of their creation, and the messages are in a chronological order in each thread, but not in comparison to other threads. The analysis revealed that threads were generally started with a why or how question, followed by students' own explanations (explicative knowledge), introduction of theoretical and conceptual explanations (theoretical knowledge), organizational messages (organize), and also some metareflections (metaknowledge).

Analysis of the discourse evolution was extended by an investigation of the knowledge advancement in the database discourse. In Table 3, the rightmost column displays the observed counts of concept definitions and report versions written by students in each thread.

As evidenced by the evolution of the inquiry, all three groups took formulated research questions as starting points for their inquiry, a practice that was emphasized by the tutors during the course by following the progressive inquiry model. The tutors had a strong role in presenting theoretical materials, but also in taking part in creating and revising questions and explanations. Only the tutor in Group C was posting messages categorized as meta-level evaluations of the process. Overall, during the face-to-face seminars, the tutors were active in promoting collaboration and reflection, asking students to present their plans initially as concept maps and then planning the reports together during two seminar sessions, and making different aspects of scientific inquiry visible.

The theme of Group A was "Qualities of networked environments that support collaborative learning." In their database discourse, the students were presenting research questions and their own knowledge and explanations regarding these questions, as suggested by the Progressive Inquiry model. Two of the discussion threads in Group A showed theoretical content introduced, two concept definitions, which was considerably less than in the other two groups, six in Group B and twelve in Group C. In the database, only one report version was uploaded. Formally this group completed their seminar report more than satisfactorily, but there was no evidence that their collaboration would have proceeded past

Table 2 Participants and messages in FLE's forums

	N	Messages f	M messages/person	Documents
Students	13	181	13.9	24
Tutors	3	57	19.0	11
Total	16	238		35

Table 3 Evolution of discourse and knowledge advancement in the three groups

Group	Thread	Discourse evolution: Q Question E Explicative knowledge T Theoretical knowledge M Metaknowledge O Organize Tutor's message	Knowledge advancement: C Concept definition V Report version
Group A	1	O O	
	2	O	
	3	T Q E E	C
	4	Q Q E T T O T	
	5	Q Q E E T E E E E Q E E	
	6	Q Q E E E E E O Q T	
	7	O	
	8	T Q E	C
	9	O M E	V
Group B	1	Q E E E E E E E E T E	
	2	Q Q E E Q T Q E E	C
	3	Q E T T T	C
	4	Q T E T T Q Q E E E	
	5	Q T T E	C C
	6	T T	C C
	7	O O O	
	8	T	
	9	O	
	10	O	V
	11	T	V
	12	T O	V V
Group C	1	T Q T	C
	2	Q E Q E E E E Q E T T M O M M M T T E Q O O T M M	C C C
	3	Q E E T T	C
	4	Q E T E E E E	
	5	E	
	6	O	
	7	Q T T O O	C C
	8	Q T	C
	9	Q T T E T	C C C
	10	T E	C
	11	T M O O O O	V V V V

each participant contributing his or her own theory piece for the report, as was also confirmed by the students during the last seminar session.

Group B worked under the theme "Creative process in a networked community." In their group, the practice of bringing in theoretical knowledge was more evident, and their

seminar reports were also written in closer collaboration, evidenced by the drafts posted. Eventually this group split their work into two final papers, one on creativity in an educational context and the other in a corporate context, written separately as a triad and a dyad, respectively. The analysis suggests that this group was presenting only a few reflections on the progress of their inquiry.

Group C was working on the theme "Teachers' and learners' roles in a collaborative networked environment." Initially, the process closely resembled Group B's process, but the messages also included meta-level evaluations in which the students themselves reflected on their process and on their understanding. They also reflected on the course materials: For example, how the articles suggested by the tutors were too focused, instead of providing a more general overview on the theme. This initiated a discussion on how, for new openings and domains (as their own research theme was), ready materials hardly exist, unlike in more established research domains. Noteworthy in Group C's process was, in particular, one long thread containing in itself a cyclic progressive inquiry process.

The section of inquiry discourse presented below shows, in our interpretation, that toward the end of the course, this group had adopted a very transparent way of monitoring collective and object-oriented activities. We considered them to be "object oriented" because they were directed at epistemic advancement: The students were negotiating which concepts needed to be explained, how to deepen the inquiry into certain questions, how to engage each member in the efforts, and how to maintain awareness on progress.

Paula
Comment: New learning models and role formation
One perspective in the formation of roles is to examine how new models of learning are seen in relation to changes in roles of teacher/tutor, student and group (compared to earlier conceptions of learning). I could make a summary of this perspective.
Other perspectives would be to approach our group's title on one hand from the point of view of the teacher and on the other hand from the student's view, also it would be good to open the concept of collaborative, networked environment (compared to the concept of cooperative, for example). (Metaknowledge)

Taru
Evaluation of the Process: What do we do now?
Yes, which way do we head?
Paula proposed that we focus on the effects of pedagogical models on students' and teacher/tutor's roles. I would add that we point out concepts like communality and knowledge creation/knowledge building and consider how they affect the roles.[…]
How the student perceives knowledge (whether right knowledge always exist, possessed by the teacher and learned by the student) is very influential on student's activity and role. I could tackle what knowledge building means and bring that deepening knowledge here.
By the way, I don't know what your feelings on our work are, but personally I find it somewhat difficult. As it is not clear what I'm doing… But, I think that we shouldn't widen our focus too much, there's a lot to chew on roles and learning, and the course it coming to its end. What do you think? (Metaknowledge)

Tiina
Evaluation of the Process: Clarifying plans
Yep, same feelings as Taru has, although I think that it starts now slowly running (as the deadline is approaching..). Both Paula and Taru's ideas and making clearer our

problem-field look good to me, because in 1 week we really cannot make very wide explorations into the issue any more.
[…] Tutor3 posted yesterday a message I found interesting on awareness about distributed expertise, which helped to clear my earlier reflections and at also helped to tie together the ideas of collaboration and knowledge building. Would you, Lauri, care to explore more for example the roles, as I understood from your talking last week, or is there a more central dimension missing from our problem-field..?
[…] It would be really good if you could post to this forum some summary of what kinds of plans you agreed on during the evening, so I'll also know what to do next.
(Metaknowledge)

This analysis of the three groups' inquiry discourse prompted questions on what was particular about Group C's inquiry process. As stated earlier, the average age of the participants and years studied was higher than in the other groups. However, it appears that there were students in Group C with particular skills for engaging in and regulating collective inquiry in the direction of advancing their shared object. According to the virtual discourse messages, they were actively monitoring whether the discourse was addressing the research questions, asking for more explanations on unclear issues, evaluating the obstacles for proceeding in their questions-explanation process (e.g., not able to find the right type of reference materials), introducing procedures to increase awareness of each others' activities, and discussing how to coauthor the report.

Self-reflections on inquiry process

For the second research question, we examined students' written self-reflections to find out how students evaluated the process themselves; that is, how they appraised the challenges of inquiry practices. The relative distribution of answer segments into the categories is shown in Fig. 1. Based on a $\chi 2$-test, there was an apparent difference between the groups in Q1

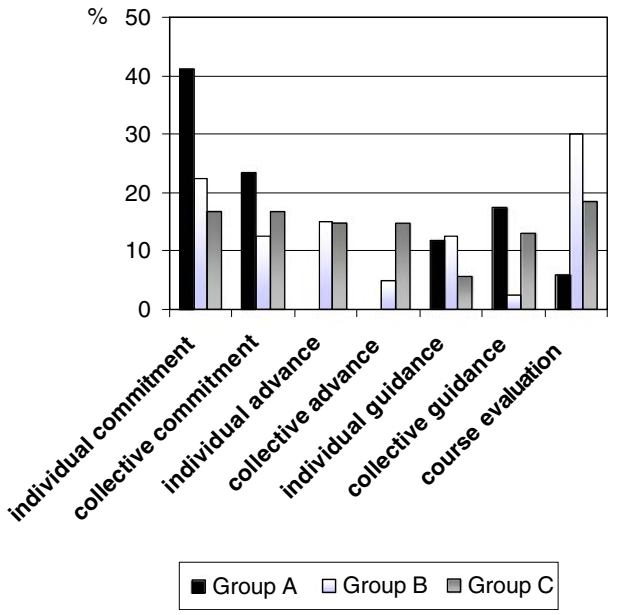

Fig. 1 Distribution of self-reflections in the three groups: commitment, knowledge advancement, guidance, and course evaluation

the distribution of self-reflections although it did not reach significance; $\chi 2$ (12, N=111)= 19.90, p=0.100.

In Group A, a large proportion of answers dealt with questions of individual commitment (41.2%) and the collective commitment (23.5%) of their group into the course and the learning process. Students acknowledged that this form of studying was new to them, and that directing the inquiry would require more of their own initiative than conventional ways of studying. One student expressed it in the following way: *One can get much more out of studying, but it takes more own initiative and activity. A student is more responsible for* [his or her] *own studying and learning results* (Pia).

The answers also reflected a view that although the students were satisfied with accomplishing their seminar report as expected, they had found the beginning of the inquiry process confusing. None of the answers of the students in Group A were coded as addressing issues of knowledge advancement, individual or collective. However, the answers did suggest that the students would have hoped for more collective guidance on the inquiry process. We interpret this to mean that they recognized the need for what we have called "object-oriented" activities.

The self-reflections of the students from group B provide evidence that they were reflecting on different aspects of inquiry than did Group A. They were addressing questions of individual commitment (23%), and course evaluation (30%); in all categories they considered more the individual than the collective aspects of inquiry. They were rather critical of their own participation, mostly in terms of limited time they had invested in the inquiry process. The substantial difference in their self-reflections compared to group A was that they clearly addressed the challenges of knowledge advancement: How to explain one's own thinking and how to develop ideas through the group's collaboration. One student reflected: *At first there was a high threshold for me to start writing my thoughts on the computer, because I had the feeling that my thoughts were not in a ready form* (Satu). They suggested that more guidance in structuring the tasks and more definite deadlines would have aided them. Furthermore, they considered this form of studying more rewarding than taking part in lectures and valued the presence of the three tutors in the discussions.

The distribution of the self-reflections in group C was evenly focused on individual, collective, and object-oriented activities: about 17% of their evaluations were both on individual and collective commitment, 15% on both individual and collective knowledge advancement, and 18.5% on course evaluation. As did students in the other two groups, nearly all of the students indicated that they could have been more active. However, they also wrote about the actual benefits of collaboration, even if the process got initially slowed down by the need to adjust to collaboration and to initialize and frame the shared object, as shown in the following quote.

> *Definitely more demanding and also harder. Nevertheless, it felt good not to be alone responsible for own work, but the whole group shared equally a responsibility for the advancement of the process. In more traditional seminars it often happens that you work on your own and on the last moment write everything ready and miss all ideas from others. Although collaboration slows work down at first, I think that it becomes a strength and richness as the process progresses* (Taru).

One student's answers suggest that she had adopted the progressive inquiry model and the principles of knowledge building for more general use in her studies. *I noticed that within another course (which happened to be simultaneously with this course) as I was working on the essay, I consciously used principles of knowledge building* (Paula). The

model appears to have provided her conceptual tools for self-organizing activities for the development of an epistemic object.

Engagement in knowledge-creating inquiry

The last two research questions, "How do the observed activities of student-groups and their self-reflections on the process relate to each other?" and "What are indications of developing skills which deal particularly with engagement in object-oriented aspects of inquiry?" take us to the intersection of the practices we observed and the self-reflections the students provided. At this intersection, we have two zones of development in sight: First, how the students carried out the work on shared objects (from the beginning until the end), and second, whether they were aware of what should have been done even if they could not necessarily carry it out at the time (proximal).

In Group A, the students produced the final report as expected, but they had not engaged in a shared idea development apart from those few seminar sessions. They had a fairly pragmatic approach to completing the task: They negotiated, during the seminar sessions, what each one would contribute; everyone provided their part; the parts were pasted together and delivered. They showed themselves to be competent in managing their individual inquiries, but not in sharing it. One student stated, *My knowledge building was left mostly on my own desk and it would have probably been better to also submit it to the collective knowledge building* (Mikko). What we consider intriguing is that all students in this group were very explicit that this kind of inquiry process was new for them and they needed more practice in it, especially because they themselves had so much responsibility for the entire process.

In Group B, according to their self-reflections, the group's collaboration worked best during self-organized face-to-face sessions, which could partially explain why there were so few meta-reflections in the database. However, they appear to have adopted new ways of engaging in idea generation in the database discourse, as expressed by one of the students: *When I noticed that the others wrote a lot of their opinions I made myself more "brave." It was great to notice how thoughts were transformed and ripened during the course* (Satu). Their inquiry process showed that they provided concept definitions throughout the process, but they were in the same format in the initial presentation and in the final report, which suggests that they were not reformulated or readdressed (i.e., treated as objects) during the process although new lines of inquiry were pursued.

The database discourse analysis generated an impression that the practice of building on each other's ideas and debating concepts flourished in Group C. This was endorsed by the students' self-reflections: *In the final stages we experienced moments that we discussed the topic of our work with new concepts and were throwing ideas in the air. We explained unclear points to each other. I feel I learned a great deal from the other students in my group* (Taru). The younger members of this group also stated that they had benefited from the skills of the more experienced students. However, there were several self-critical voices in evidence, which described the processes as half-ready and the collaboration as just starting to function properly. Looking at the process in comparison with the other two groups, such self-criticism is surprising. Comprehensively, in the self-reflections the Group C students more often addressed the collective and object-oriented aspects of monitoring inquiry, whereas the other two groups dealt more with the individual and collective aspects. Considering these findings together seems to suggest that for the students in Group C, coordinating the activities around the shared object was not unproblematic, but they had created practices for it and were reflecting on how these

practices could have been improved. Further, they appear to have gained the full benefit of the heuristic support for inquiry provided by the progressive inquiry model, although they were not facilitated in it more than the other two groups.

Discussion

The activities of three student-groups were examined to find out how university students engaged in collaborative knowledge-creating inquiry. Based on the first research question, the analysis of the database discourse suggested that students were aiming at question-driven inquiry, and each group's inquiry had a common object, a collaborative writing task, to answer inquiry questions they had devised. During the meetings, the tutors used systematic methods to facilitate the development of groups' question-explanation processes and plans for collective seminar reports. Further support was provided by the FLE3 environment which offered scaffolds for written contributions.

An analysis of the discourse evolution provided evidence on varying practices of inquiry. In Group A, the seminar report was constructed with very little collaborative interaction and could be described as a product of three individual inquiries. Generally, this kind of strategy works well under the pressure to get a job done expeditiously; hence, the type of "pasting together" activity also makes sense. In Group B, the members did collaborate significantly more in order to advance their understanding on the research questions they had produced. However, in Group C, this collaboration was equally observed, but it had a distinct quality; students produced more conceptual definitions, debated their conceptual understanding, and also, importantly, versioned their work more than did the other groups.

The second research question on students' self-reflections yielded evidence that, in every group, students emphasized the importance of their own efforts, that this was a new way of studying for them, which required more initiative and responsibility and that they would need more practice to get better at it. This is in line with the objective of fostering the development of agency and academic literacy. In general, the students portrayed the collective and object-oriented aspects of inquiry as both rewarding and demanding. A number of students wrote that scientific argumentation was difficult, but that the model provided by older students and tutors was valuable.

The third research question addressed in parallel the observed activity of student-groups and their self-reflections. It provided a number of points of interest: First, when our analysis suggested that the students did not engage in a collective process or iterate the shared object, the students wrote about issues of commitment and only individual aspects of inquiry (Group A). Second, when the database analysis suggested that the group did engage in discussing and explication of ideas but not in a further revision or elaboration, the students reflected on the coordination challenge and only secondarily on the knowledge-creation challenge (Group B). In the last case, Group C, when the database analysis suggested a collaborative knowledge-creation process, the students reflected comparatively less on the individual aspects of monitoring inquiry. Although they concentrated on collective and object-oriented aspects of inquiry, they were also relatively self-critical about the process.

Our last research question was "What are the indications of developing skills which deal particularly with engagement in object-oriented aspects of inquiry?" Here the activities of Group C are illuminating: They actively monitored and took charge of insuring that the discourse was directed at addressing the research questions, asked for more explanations on

unclear issues from each other and the tutors, and evaluated the obstacles in their questions-explanation process. Further, they introduced procedures to increase awareness of each others' activities and practices for coauthoring the report.

The findings suggest that, particularly for younger students, knowledge-creating inquiry was a novel experience and required competencies not previously called for in their undergraduate studies. Especially in Groups A and B, we encountered difficulties in finding ways to direct the inquiry toward advancing the shared object. Apparently, the tutors did not correctly assess the students' need for support, so they got less than would have been adequate to ensure their engagement in the new practices.

Conclusions

We propose to frame the notion of metaskills so that they deal with social practices of engaging in collaborative inquiry, which operate on a collective object. Our findings suggest that these are practice-bound skills for turning attention to critical aspects at hand and making activities transparent to other participants, although it is not clear how well one is able to explicate this knowledge during the process. Furthermore, we envision that the knowledge-creation challenge sets the expectation that the epistemic "quality" of the knowledge objects to be developed is central, which, in turn, cannot be fulfilled without a collective commitment to knowledge advancement. How one is able to observe metaskills when they are put to practice cannot be equated with one agent's activities; rather, the metaskills available in an inquiry are derived from the activities of the set of active participants.

As Nonaka and Takeuchi (1995) have argued, a community's tacit knowledge is transformed to an agent's personal tacit knowledge through socialization. Therefore, it is proposed that metaskills, as any expert skills, are developed through long-standing socialization into inquiry cultures (Hakkarainen et al. 2004). From this perspective, it follows that metaskills may be facilitated through engaging students in shared inquiry practices. When these practices are designed in a way that elicits collective and object-oriented regulation of inquiry, corresponding metaskills may be elicited as well.

Our empirical data are from a course of 11 weeks, making it a very short timescale for examining the development of such skills. However, we gained two insights from the study: First, we observed that the older students were more able to direct their activity toward a collective, object-oriented process. This offers one hypothesis to examine, which needs to be verified with further research. Second, taking the dual approach of observing the activities in the database and the self-reflections, we gained an understanding of the novel challenges evoked by knowledge-creating inquiry, pertaining in particular to commitment, epistemic involvement, dealing with confusion, and the iterative nature of knowledge advancement. However, further research is needed to address a fuller range of metaskills for knowledge-creating inquiry, as this case study provides an initial exploration into the issue.

To arrive at true knowledge-creating practices, a high standard for the epistemic involvement in knowledge advancement efforts needs to be adopted. In educational contexts, one may take the stance that the objective is creation of locally novel knowledge, that is, to arrive at new conceptual understanding, practices, or solutions for the learning collective. Regardless of the rigor in defining the standards for knowledge creation, a central focus of activity should be that the knowledge-creation objective be furthered, and that the practices conducive to it be nurtured. This can be actualized by placing an emphasis on drafting, commenting, versioning, and reediting, which relies on the iterative nature of knowledge advancement. In these processes, the object is explicitly sought and developed.

Further, metaskills encompass the ability to generate strategies for pursuing inquiry and improving the object (despite difficulties and controversies), to tolerate the confusion of a novel endeavor, and have trust in finding the focus (with appropriate scaffolding and feedback). It appears crucial to maintain focus throughout the process on the big question and its associated object. It is, in our view, pedagogically important to facilitate the process in such a way that the ill-defined quality of the process is addressed as a central characteristic of knowledge creation; participants do well to learn to address and manage the uncertainty that is an essential aspect of knowledge-creating practice.

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Appendix A

Table 4 Discourse evolution analysis categorization and descriptive examples

Category	Purpose	Descriptive example
Question	Asks research problems that call for explanation of understanding	*Problem: Creative environment? How important is the effect of the environment on the progress of a creative process? How to make the environment creative?* (Ella, Group B)
	Presents a research problem to be addressed	
Explicative knowledge	Presents own explanations, experiential knowledge, ideas, or perspectives	*Comment: Can a networked environment be creative?*
	Presents own hypothesis or wonderment, including questions, but the questions do not have a central position	*I believe that the environment may have a big impact on how an individual discloses creativity. In my opinion the interaction between individual and the environment is based on the application of creativity and at the same time it generates new ideas. In a classroom, a teacher typically tries to create with his or her own activities a sociable and free atmosphere, where students find it easier to express themselves creatively. Of course, the interactions between students affect how creatively a person dares to act.* (Satu, Group B)
Theoretical knowledge	Presents theoretical concepts, models, theories, or research findings. Presents the source of knowledge with the knowledge.	*Scientific Explanation: What is creativity?*
	Makes a conceptual contribution to inquiry	*[]Mathematician Poincaré has presented a four phases model of creativity:* *1. preparation – knowledge acquisition* *2. incubation – unconscious process* *3. insight, illumination – transient insight* *4. verification, elaboration; phase dependent on the field of action.* *Does creativity have limits? My claim is that an individual creativity has no limits, but that certain external frames may clarify the problem and assist the process; too*

Table 4 (continued)

Category	Purpose	Descriptive example
		much liberty may become a burden. (Sari, Group B)
Metaknowledge	Reflects one's own or group's understanding Reflects on changes in the produced knowledge.	*Problem: Relevance of articles from perspective of a short course*
	Presents an evaluation of how the group's work is advancing.	*[]There is a problem of relevance with the articles (at least some of them), which we already discussed in the group. It is that a part of the articles cover single research experiments and because the course is so short, it's impossible for a student to make summaries (or critically reflect on them considering the research context) just based on single research and their findings presented in articles. I consider that more appropriate sources would be different ready summaries, which draw together general lines on research findings. […] It would be ideal if there was enough time for focusing on a couple of research articles and the general lines.* (Paula, Group C)
	Presents alternatives for how to elaborate.	
	Sums up prior discussion and knowledge products.	
Organize	Organizes collaboration.	*Problem: The slides of our presentation*
	Info on posts.	*The slides of our presentation (Tomi and me) can be found on my web-top.* (Pauli, Group B)
	Tutor posts concept maps.	

Appendix B

Table 5 Challenge of inquiry practices analysis categorization and descriptive examples

Category	Focus of reflection	Descriptive example
Individual commitment	*Individual monitoring of inquiry*: Student explaining and evaluating their own participation and commitment to the inquiry.	Requires clearly a new approach to studying, to benefit from knowledge building. Would need to change own studying strategies — but its not so easy after the last 18 years doing things "the other way." (Pauli, Group B)
Collective commitment	*Collective monitoring of inquiry*: Student addressing the challenges of working together and being dependent on each others' participation.	As in university studies more generally, here also it became evident the very different levels of commitment and goals for the course between the students, which partly influence how the course turns out. (Tiina, Group C)
Individual knowledge advancement	*Individual and object-oriented monitoring of inquiry*: Considering how one's own understanding advanced, how one's own thinking changed, What difficulties were encountered in the question-explanation processes, and how one's own writing efforts progressed.	While reading the articles in English, understanding the concepts was really troublesome: it was so difficult to figure which concepts corresponded to which Finnish concepts, and vice versa, which ones of the concepts raised during the lectures were in the articles. (Paula, Group C)

Table 5 (continued)

Category	Focus of reflection	Descriptive example
Collective knowledge advancement	*Object-oriented and collective monitoring of inquiry*: Explaining how ideas developed in relation to shared efforts, how one person's ideas were elaborated by others. Emphasizing ideas and the report versions (artefacts) produced in collaboration.	Course work felt really difficult and laborious, but now afterwards I would say that all the work was worth it. Even if the process was not completed, it taught a lot. I believe that our final report was beyond what any of us could have done alone. (Taru, Group C)
Individual guidance	*Individual monitoring of inquiry*: Explaining what kind of guidance or scaffolding would have been useful for personal advancement. Assessing need for individual guidance.	Perhaps more on theories of psychology, now it felt like that without own strong base in the subject, I had to rely on some reference without the ability to assess its merits or then personal views type of comments. (Pauli, Group B)
Collective guidance	*Collective and object-oriented monitoring of inquiry*: Assessing the needs and providing suggestions for how to improve the guidance for collaboration and knowledge creation.	The creation of working theories could have been more guided, in my opinion we headed directly to the sources to look for knowledge. (Lauri, Group C)
Course evaluation	*Course design and tools support*: Discussing the working format (progressive inquiry), the FLE-environment, how well the course matched expectations, or how the course succeeded. Assessing design aspects of the course and the tools.	In the Web-learning environment it was hard to get an overview of the discussion. It would be handy to have an easy functionality, which would present hierarchically all the texts you want (and print them). (Paula, Group C)

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