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Teachers' pedagogical designs for technology-supported collective inquiry: A national case study

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Abstract

The aim of the present study was to analyze teachers' pedagogical designs, plans of organized technology-supported, collective student inquiry. Ten teachers in Finland designed and implemented eight, inquiry-learning units ('designs') in 12 primary and secondary level classrooms in various subject domains. The guiding principles behind the designs were the objectives of progressive inquiry, such as facilitation of question- and explanation-driven learning, and the use of collaborative technology to support the sharing of knowledge. The participating teachers received substantial pedagogical training on these issues before the classroom implementations. The present study concentrated on examining three aspects in the teachers' pedagogical designs: solutions for supporting students' inquiry efforts, organization of collaboration, and the role given to the web-based Collaborative Learning Environment (CLE). The teachers experienced the use of CLE as a valuable new possibility to foster collaboration in classroom work, but there was much variation in the ways that the affordances of the system were utilized. The results indicated that it was a challenge for the teachers, especially in secondary level, to find appropriate methods for supporting students' inquiry efforts. The most difficult aim to achieve appeared to be the promotion of real collaborative knowledge building; the social arrangements of many designs still relied on rather individualistic ways of working.

Keywords: Cooperative/collaborative learning; Distributed learning environments; Pedagogical issues; Teaching/learning strategies; Evaluation methodologies

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1. Introduction

One of the basic requirements for present-day education is to prepare students for the knowledge society and knowledge work. Knowledge work is characterized by systematic knowledge advancement, sharing of expertise, and collaborative elaboration of knowledge products. Several researchers have proposed that in order to advance skills required in this kind of activity, cultures of schooling should more closely correspond to cultures of scientific inquiry (e.g., Carey & Smith, 1995; Edelson, Gordin, & Pea, 1999; Hakkarainen, Palonen, Paavola, & Lehtinen, 2004). This includes contributing to collaborative processes of asking questions, producing theories and explanations, and using information sources critically to deepen the community's conceptual understanding. Scardamalia and Bereiter (1999) have proposed in their knowledge building theory that schools be restructured towards knowledge-building organizations, in which students and teachers participate in the construction of collective knowledge as in professional research groups where the object of activity is solving knowledge problems. New pedagogical models are required that would support such practices in education.

The best practices in advancing knowledge-building pedagogies combine socio-cultural aspects of learning, pedagogical models that emphasize higher-order inquiry activities, and appropriate use of collaborative technology (Edelson et al., 1999; Hakkarainen, 2003a; Lehtinen, 2003; Scardamalia & Bereiter, 1994); they have gradually spread to schools through piloting teachers, teacher-training organizations, and educational researchers. Nevertheless, the dissemination of the elaborate practices in ordinary schools, in a large scale, has not been systematically investigated. Many studies have revealed that practices of inquiry and collaboration with other learners can be very demanding for students and, therefore, require considerable support (see Veermans & Järvelä, 2004). As Krajcik, Blumenfeld, Marx, and Soloway (2000) wrote: "Students need help to become knowledgeable about content, skilled in using inquiry strategies, proficient at using technological tools, productive in collaborating with others, competent in exercising self-regulation, and motivated to sustain careful and thoughtful work over time." (p. 248). Previous studies have reported, for example, the following shortcomings in the students' activities when implementing technology-supported inquiry practices in school learning: cognitive demands of inquiry (Brown & Campione, 1994), low epistemic quality of produced knowledge (Lakkala, Ilomäki, Lallimo, & Hakkarainen, 2002), low sustainability of the discourse (Hara, Bonk, & Angeli, 2000; Hewitt & Tevlops, 1999), heterogeneity in participation (Lipponen, Rahikainen, Lallimo, & Hakkarainen, 2003), and the teacher's dominating role in discourse (Guzdial, 1997).

A crucial element in overcoming the above-mentioned problems is the teachers' pedagogical competence in supporting students' collective inquiry efforts. First, teachers have to understand the basic theoretical principles behind the advanced pedagogies: problem-driven knowledge seeking, the role of students' prior knowledge and self-explanations, engagement in a sustained process of deepening understanding, and conceptions of knowledge building pedagogy and distributed cognition (Hakkarainen & Sintonen, 2002; Salomon, 1993; Scardamalia, 2002). Second, an even bigger challenge for a teacher is to apply these theories in practice: how to organize the inquiry efforts and collective activity, how to find successful methods for scaffolding groups of learners, and how to use web-based technologies in a sophisticated way. In educational settings intended to foster the practices of collective inquiry, the teacher's role is changed, from delivering knowledge or designing pre-formulated tasks, to organizing the community's activities and establishing the underlying conditions in the learning environment (Hogan & Pressley, 1997; Wells, 2000), and to building up appropriate infrastructures for collective effort (Bielaczyc, 2001; Lipponen & Lallimo, 2004).

In order to find better ways to support teachers and schools in developing their pedagogical practices, the current efforts to implement technology-supported collective inquiry in special units in several classrooms should be critically evaluated. The present study examined such efforts of ten Finnish primary and secondary teachers as part of a larger European development project. The teachers carried out inquiry learning units in their classrooms in various subject domains using the same web-based Collaborative Learning Environment (CLE). The main goal of the study was to evaluate the teachers' efforts to apply technology-supported collective inquiry in their classroom practice, in order to better understand the demands which fall upon teachers when they adopt a pedagogical innovation, i.e., when they are provided with appropriate training and technology. The study investigated *pedagogical designs*, a term we use to indicate plans of organized technology-supported, collective, student inquiry; the implementation of these plans being in the form of inquiry-learning units on various topics. The term 'design' as used herein will refer to the plan, the manner of organization, and the actual implementation of such in the unit of study. The pedagogical design of an educational setting establishes conditions for the inquiry culture to emerge, and therefore has a crucial role in fostering collective inquiry.

In analyzing the pedagogical designs of classroom settings applying collective inquiry approach, the unit of analysis is the collective activity as a whole, rather than merely the contribution and advancement of individual participants (Salomon & Perkins, 1998). A holistic analysis requires the combining of various data sources and analysis methods in a functional and systematic way (Rogoff, 1995). In addition, it is a challenge to describe and consistently compare the varying educational settings, using the same theoretical concepts and structures. It is necessary to set up a generic framework, which can be used to investigate the implementation of technology-supported collective inquiry in various educational settings.

2. Infrastructures for technology-supported collective inquiry

Bielaczyc (2001) argued that in educational change through collaborative technology, the central challenge lies in building the appropriate *social infrastructure* around the *technical infrastructure*, including classroom culture, philosophy and norms established, classroom practices and online activities fostered, and the usage of technology for collaboration. Paavola, Lipponen, and Hakkarainen (2002) suggested, further, that besides technical and social infrastructure, educators and researchers should also consider the *epistemological infrastructure* of a learning community, manifest in the community's activities oriented towards knowledge advancement. In addition, Lipponen and Lallimo (2004) have elaborated on Bielaczyc's idea. They proposed that establishing a social infrastructure should be the primary objective; i.e., instead of arranging activity around technology, technology should be subordinate to social infrastructures.

But what does it concretely mean, to build up appropriate epistemological or social infrastructure for collective inquiry? In the present study, the building up of epistemological infrastructure was defined according to the nature of the learning activities designed to support sustained, question-driven inquiry. As Winn (2002), and Krajcik et al. (2000) stated, the advancement of inquiry is dependent on the teacher's practices in guiding the community's efforts, and supporting the development of students' metacognitive awareness of the inquiry strategies by adequate scaffolding, e.g., by modeling the process, or phasing the inquiry activities. In general, students do not spontaneously engage in metacognitive thinking unless they are explicitly encouraged to do so through carefully designed instructional activities (Lin, 2001). However, too much control restricts the students' own cognitive efforts, and may result in externally directed, artificial activity (Scardamalia, 2002; Strijbos, Martens, & Jochems, 2004). For example, Ng and Bereiter (1991) found that learners who had personal knowledge-building goals in the learning situation, outperformed learners that had goals focusing on the completion of assigned tasks or following the given instructions. *The support for inquiry* in the pedagogical designs was evaluated by analyzing (a) whether the task assignments directed students' activity towards purposeful inquiry, and (b) whether the use of inquiry strategies was promoted and scaffolded by adequate structuring of the activities.

The emergent social infrastructure was examined, as it was manifest in arrangements that organized students' collaboration. Genuine collaboration does not usually appear on its own, without teachers' deliberate efforts and organization of the community's activities (Dillenbourg, 2002; Winn, 2002). For instance, Kreijns, Kirschner, and Jochems (2003) have noted the following pitfalls of social interaction in instructional activities applying collaborative technology: taking it for granted that participants will socially interact simply because it is possible; and neglecting social psychological and socio-emotional aspects of interaction because of sole focus on cognitive processes. *The organization of collaboration* in the pedagogical designs was evaluated by analyzing (a) whether the task assignments directed students' activity towards individual or collective efforts and results, and (b) whether the students' collaboration was promoted and scaffolded by explicit social arrangements.

The utilization of the affordances provided by the technical infrastructure was evaluated by examining the role given to the technology in the pedagogical designs. The access to sophisticated new technologies, and sufficient technical skills for using them does not necessarily guarantee that teachers will use the possibilities of technology for changing the pedagogical practices (Salomon, 2002). Collaborative technology can be used for various purposes from knowledge delivery to real collaborative knowledge building (Lipponen & Lallimo, 2004; Bereiter & Scardamalia, 2003); the teacher's pedagogical design, and instructions for students direct the learning community's way of using the tool. In the present study, *the role given to the collaborative technology* was investigated; we examined (a) the use of the CLE for knowledge sharing between the participants, and (b) the teacher's own contribution, compared with the students' contribution, in producing and sharing knowledge in the CLE.

3. Methods

3.1. Setting

The investigated, collective inquiry designs were undertaken in the Finnish test sites during the ITCOLE project (see http://www.euro-cscl.org/site/itcole/) funded by European Union. In the first testing phase of the project, ten teachers participated in pedagogical training, and testing of the software. In the second phase, they implemented the pedagogical models and the software in primary and secondary level teaching groups in various subject domains. The designs, the implemented plans of these inquiry-learning units were analyzed and evaluated in the present study.

A central emphasis in the Finnish experiments in the ITCOLE project was to provide adequate pedagogical training and support for the participating teachers. The teachers received four days of training before the classroom implementation about the issues of collaborative technology, knowledge building theory, inquiry-based learning, web-based education and change management. In addition, the pedagogical design and implementation of technology-supported collective inquiry was supported by consultation (about 25–30 consulting occasions in all), pedagogical workshops (about 6 days), and virtual meetings between the participating teachers and the trainers (for details of the training, see Haatainen & Korhonen, 2002). The present researchers participated in some of the training sessions and virtual meetings as expert participants, but did not directly influence the teachers' pedagogical designs.

The pedagogical model provided to support the Finnish teachers' and the students' efforts to adopt collective inquiry practices was progressive inquiry, developed by Hakkarainen and his colleagues (Hakkarainen, 2003a; Muukkonen, Hakkarainen, & Lakkala, 2004) as a pedagogical and epistemological framework for facilitating expert-like working with knowledge in educational settings. In progressive inquiry, students' genuine questions and previous knowledge of the phenomena are a starting point of a deepening process, in which students and teachers explain phenomena, share their expertise and build new knowledge collaboratively with the support of technology. The progressive inquiry model specifies certain epistemologically essential processes that a learning community needs to go through, while the relative importance of these elements, their order, and actual contents may involve a great deal of variation from one setting to another. The objective is not to follow the elements mechanically, but to offer conceptual tools to discuss and make visible the strategies and activities in the inquiry practice. The progressive inquiry model has been applied in various educational settings at primary and secondary levels (Lakkala et al., 2002; Lipponen, 2000; Veermans & Järvelä, 2004), and in higher education (Muukkonen et al., 2004; Lahti, Seitamaa-Hakkarainen, & Hakkarainen, 2003).

The CLE used in the investigated experiments was version 1.0 of the Synergeia BSCL (Basic Support for Collaborative Learning, see http://bscl.fit.fraunhofer.de) system, developed during the ITCOLE project. In the threaded discourse areas of the system, progressive inquiry is promoted by asking each user to categorize each note by choosing a 'thinking type' for it (Problem, Working theory, Deepening knowledge, Comment, Reflection on the process, Summary, and Help). The idea is to provide learners with procedural facilitation for their cognitive efforts, and develop metacognitive awareness of inquiry strategies while using these scaffolds (see Scardamalia & Bereiter, 1994).

3.2. Participants and data collection

Ten teachers from eight schools participated in the study. Seven of the teachers were males. Three teachers were class teachers from primary school, which includes 6 grades; four teachers were subject teachers (native language & ICT; fine arts & media education; native language & history; and math, science & ICT in special education) from lower-secondary school, which includes 3 grades; and three teachers were subject teachers (philosophy; history & economics; math &

languages in special-education) from upper-secondary schools, which includes 3 grades. The average age of the teachers was 37.8 years (SD = 6.7), and the average number of years teaching was 11.0 years (SD = 6.7). The teachers were experienced in using computers in teaching, and only one lower-secondary teacher reported that he did not have previous experience in web-based collaborative technologies.

The ten teachers created, in all, eight different pedagogical designs for their students applying the ideas of progressive inquiry and the use of the CLE. In all, 12 teaching groups, and 235 students, participated in the inquiry-learning units; four of the eight designs were carried out in a similar way in two teaching groups. The size of the teaching groups varied from 6 to 32. Mean size of the teaching groups was 19.6 students (SD = 8.2). The youngest students were 10–11 years old, and oldest were 17–18 years old. Children in Finland start schooling at seven years of age.

The teachers wrote reflective notes weekly during the inquiry-learning units, and sent them to the researchers by e-mail. Afterwards, the teachers were interviewed with a semi-structured interview lasting approximately one hour, and the teachers wrote a report about their pedagogical designs describing the context, goals, and procedures in the unit, and their own evaluation of the process. The data in the study consisted of these writings and interviews, and the contents of the database in the Synergeia BSCL system created by the teachers and the students in the course of the inquiry-learning units.

3.3. Collective inquiry designs

The teachers carried out the inquiry-learning units as part of the ordinary curriculum, and they decided themselves, which lessons and how many hours they would allocate for them. In Table 1 is presented a summary of the designs, based on the teachers' reports and database analysis.

3.4. Data analysis

As mentioned, the teachers' pedagogical designs had to be examined using multiple data sources and analysis methods. For inspection and analysis, the designs, so to say, had to be reconstructed from the teachers' descriptions and the database structure. For that reason, the investigative approach was the combination of qualitative and quantitative methods, in order to provide a multi-faceted and comprehensive picture of the designs. ATLAS/ti program was used for all qualitative analyses.

Both *the support for inquiry* and *the organization of collaboration* in the investigated designs were examined by qualitatively analyzing the teachers' own descriptions of the inquiry learning units in reflective notes, written reports, and transcribed interviews. First, based on a preliminary analysis of the data, a categorization was developed to define the support for inquiry, and to make evident the organization of collaboration in the designs. The categories are described in Tables 2 and 3. Second, those excerpts of the data were chosen for detailed analysis, in which the teachers described, especially, the features of tasks and activities, inquiry process, and organization of collaboration in the inquiry-learning units. Third, each chosen excerpt was coded in the design categories according to its content. One design may have included multiple features under each main category. Fourth, for each design, those features that had the main emphasis

Table 1
Inquiry learning units investigated in the study

Topic	Subject domains	School grade	Age of students (years)	# of students	Duration (weeks * hours/week)	Special features
Why does the globe rotate?	Natural sciences, native language, arts	Primary 4th	10–11	28 + 27	14 * 3 h	Two classes from the same school conducting similar inquiry units and collaborating a little
All roads lead to Rome	History	Primary 6th	12–13	28	12 * 3 h	Inquiry in one class; both the teacher and the students were experienced in using CLEs
The national epic Kalevala	Native language	Lower secondary 3rd	15–16	10 + 20	14 * 1–2 h	Collaboration between an ordinary and a special education class through the CLE
Culture course	Multidisciplinary	Lower secondary 3rd	15–16	15	10 weeks (no fixed lessons)	Partly distance learning; optional course; students chose varying themes
Human is what he eats – Youth in media	Media education	Lower secondary 3rd	15–16	23	12 * 2–3 h	Optional course; students participated to the discourse forums during lessons, but read up on materials from varying media also at home
Sources of financing and Finland's financing market	Economics	Upper secondary 1st	16–17	14, 19	12 * 3 h	Two separate teaching groups studying the same unit. Students produced a collaborative report in groups of two or three students
The philosophy of Matrix movie	Philosophy	Upper secondary 1st	16–17	32	6 * 5 h	Virtual collaboration also with some foreign students around Europe; only discourse forums in use
Reading and Writing in Special education	Learning skills (texts about biology, psychology and philosophy)	Upper secondary 2nd–3rd	17–18	6, 13	6 * 5 h	Special education; two separate teaching groups studying the same unit. The first group was from one school, the second one included students from two schools. Many pre-defined tasks

Table 2
The categorization used for examining the support for inquiry in the investigated designs (teachers' descriptions are translated from Finnish)

Category	Description	An excerpt from the data coded in the mentioned category (Design #)
Epistemic nature of activities		
Task-accomplishment	The goal of activity was described to be the completion of certain tasks, preparation of a project work on a chosen theme, or passing through certain courses	After that they were given a task, in which they follow news discussing this topic in mass media about two weeks, and based on the news they make a small summary. (5)
Sharing of ideas	The goal of activity was described to be the sharing of ideas with each other (through the CLE)	We attempted to construct common knowledge in the knowledge-building forum of the course without own research questions. (8)
Purposeful inquiry	The goal of activity was described to be the accomplishment of purposeful inquiry by defining and answering research questions	The research question was chosen from the large number of questions invented together. The students choose the question that interests oneself. The groups became theme-based groups, based on the closeness of the topic of the research questions. (1)
Structuring of the activity		
Rigidly structured activity	The activity was structured by separate highly-defined tasks that were done successively	Along with the project, also other tasks were done. The group was divided in two once in a while so that the turn was switched in the middle of double lesson. Doing many tasks simultaneously might have felt confusing for students. However, it enabled smooth advancement and directing. (3)
Open inquiry	The activity was based on students' open inquiry and discourse activity without explicit structuring	This time I gave the students relatively plenty of rope to make their project, but it was not necessarily exactly the right decision. (6)
Scaffolded inquiry	The inquiry process was structured by explicit phasing or modeling of inquiry strategies	Last week, the most important task was to think about deepening questions based on the feedback and the knowledge building discourse. This week, we have progressed deeper in the research project by searching for new information in the third phase. (2)

in the students' activity, were defined separately, based on the overall view of the design that the analysis brought.

The contents of the databases in the CLE (e.g., structuring of the shared areas, or the teachers' written guidelines and assignments) were used as complementary data to ascertain the categorization. The categorization is an explorative and descriptive analysis framework meant for holistic analysis of the designs, and the present researchers, together, analyzed the data by several iterative analysis cycles to enter into agreement.

Table 3
The categorization used for examining the organization of collaboration in the investigated designs

Category	Description	An excerpt from the data coded in the mentioned category (Design #)
Social nature of activities		
Individual activities	The participating students were required to accomplish certain activities individually	So, the course participants have now their own learning logs, in which they invite the teacher as a member, and which nobody else is able to read. (8)
Individual product	The participating students were required to produce an individual product or final work	The students have revised their research work and moved the last version into their own folder, and written their own evaluation both about Synergeia and about their research work in the teacher's and the student's common discussion folder. (1)
Collective activities	The participating students were required to accomplish certain activities together	In the end of the week, we carried out in small groups (all members had the same research problem) a Maptool session, in which the small group made a mind map about their common research topic. (2)
Collective product	The participating students were required to produce a collective product or final work	The project ended so that during the last two meetings the groups made an essay of their question, which was returned to Synergeia. (6)
Structuring of collaboration		
Open collaboration	Collaboration between students was open, based on spontaneity and general encouragement	The students were encouraged to actively familiarize themselves with the productions of others, and to seek collaboration with those students that work with similar problems. (5)
Scaffolded collaboration	Collaboration between students was systematically structured by grouping or by collaborative working methods	The progressive inquiry project was ended to a course summary in knowledge building areas, for which new groups were founded. Each new group had only one member from the first small groups; so, only he had knowledge accordant with his research question about ancient Rome. (2)

The role given to the collaborative technology was examined by counting several quantitative measures of the shared knowledge in the database; such as the number and type of the artifacts (discourse notes, documents, links) produced, and the teachers' and the students' relative activity in the knowledge sharing.

In addition, excerpts from the teachers' answers in interviews were used descriptively to illustrate the teachers' own conceptions of their designs. The excerpts used in the text are translated from Finnish.

4. Results

4.1. Support for inquiry

The nature and structuring of the learning activities in the eight collective inquiry designs were, first, analyzed concerning the support for inquiry they provided. In Table 4 are presented the results of the analysis.

As can be seen from Table 4, the designs differed a lot from each other as regards the nature of the learning tasks and activities. Three designs (Globe, Rome and Matrix) can be described as 'simple' ones, in which the nature and structuring of activities were consistently designed following one leading approach. In the two primary classroom designs (Globe and Rome), the design appears to most strictly have followed the model of progressive inquiry: The students' genuine problems were the central focus of the activity, and the inquiry process was supported by explicit structuring and modeling of critical inquiry strategies. Also, the primary teachers' own reflections in the interview about their designs indicate that they deliberately aimed to structure the inquiry process to help the students become more aware and competent in the inquiry strategies (e.g., "It has become more as a conceptual model for me as a teacher, and also for the students, and as a natural way to work. We are just constructing some mechanisms, which can be utilized. We practiced skills that can be used and applied in all mental activities in the future. It was perhaps fumbling in the beginning, but it was good to practice the skills with so small students, because there were no problems with learning out old practices or with resistance for a change"). In the Matrix design, the leading approach more resembled an open sharing of ideas without much direct structuring or demands for performance. The teacher appears to have relied on students' abilities to spontaneously accomplish purposeful discourse, but afterwards he concluded that he should have controlled the process more directly ("Probably I made a mistake in letting the learner think about the questions too much. I should have done so that I think over the questions myself and we proceed, at least partly, with the help of them. It would have sped up the process").

Table 4
Support for inquiry in the investigated pedagogical designs

Support for inquiry	Primary		Lower secondary			Upper secondary		
	Globe[a]	Rome	Kalevala[ab]	Culture	Youth	Finance	Matrix	Read & Write[b]
Epistemic nature of activities								
Task-accomplishment			○	●		○		●
Sharing of ideas				○			●	○
Purposeful inquiry	●	●	●		●	●		
Structuring of the activity								
Rigidly structured activity			●	●	○	○		●
Open inquiry			○	○	●	●	●	○
Scaffolded inquiry	●	●	○			○		

The emphasis in the designs was in those features that are marked with black dot, but the features marked with white dot were also present in the design.
[a] Two teachers.
[b] Special education.

In the other designs, the nature and structuring of the activities was more mixed. In the designs of Kalevala, Youth and Culture, the teachers' objective apparently was to promote purposeful inquiry, but the students' activity was partly structured by means of separate, highly defined tasks. It seems that the teachers did not know how to support the inquiry activity, and noticed the need for more support only afterwards (e.g., "I will put much more effort on the creation of course, the organization of materials, and structuring of the activity. Now I used the system as such, to see how it works, and how it supports progressive inquiry. I did not have enough experience to make the design complete. I noticed that the teacher is very much needed in such approach").

In the Culture and the Read & Write designs, the nature of activity was analyzed to be more 'traditional' task-accomplishment or project work, not actual purposeful inquiry. Both designs were composed of several pre-structured tasks and activities for students, and the inquiry assignment was merely one activity among others. In the interviews afterwards, the teachers of these two designs also emphasized the need for guiding students to fulfill the requirements and to complete the tasks rather than supporting the inquiry strategies (e.g., "Then I would be more strict in the starting phase, so that if there will not be working versions of the report in Synergeia, I would be angry, and would go to bluster about it, or I will ask for the learning log even more briskly").

One comparison can be made between the two special education designs (Kalevala and Read & Write). The special education teacher of the Kalevala design – who worked with students with severe problems with schooling and in danger of dropping out of the school system – appears to have aimed at student-centered, open-ended inquiry, and he genuinely tried to find ways to help his low-level students learn the crucial skills ("I am rather surprised that I have learnt to trust that rather open problem-solving approach gives results. It was applicable also in other school subjects, and it creates competencies for further studies"). The teacher in the Read & Write design concluded, instead, that conducting their own inquiry was too demanding for some students; her solution was to return to more traditional methods and tasks defined by the teacher ("The advancement of own research problems failed. There is no time to advance one's own research process besides other course exercises during one period. So, in the other period I completely left out the elaboration of research problems. We got acquainted with the progressive inquiry cycle, and I clarified what it is about. But I did not demand own research topics").

It is noteworthy that in the interviews seven teachers out of ten brought up, especially, the issues related to scheduling of the process when they were asked: "What would you do differently next time?" The teachers experienced difficulty in scheduling this kind of progressive, sustainable activity, while there is only a few lessons for it, weekly, among other tasks and activities; computers were not always available; and the curriculum established time limits for the work (e.g., "Next time I would make the project in much shorter time and preserve the time allocated for it completely from other tasks" or "Maybe the compactness, one should pay more attention to it. So that we remain in sensible time limits, by carelessly reserving time from the computer class, or by making the project more intensive").

4.2. Organization of collaboration

We analyzed also the ways in which the students' collaboration was organized in the designs. In Table 5 are presented the results of the analysis for organizing collaboration.

Table 5
Organization of collaboration in the investigated pedagogical designs

Organization of collaboration	Primary		Lower secondary			Upper secondary		
	Globe[a]	Rome	Kalevala[ab]	Culture	Youth	Finance	Matrix	Read & Write[b]
Social nature of activities								
Individual activities			○	○	○	○		●
Individual product	○	○	○	●	○	○		○
Collaborative activities	●	●	○	○	○	○	●	○
Collaborative product	●		●	○		○		
Structuring of collaboration								
Open collaboration			○	●	●	●	●	●
Scaffolded collaboration	●	●	○			○		

The emphasis in the designs was in those features that are marked with black dot, but the features marked with white dot were also present in the design.
[a] Two teachers.
[b] Special education.

The analysis of the arrangements for collaboration revealed some interesting trends. In the primary level designs Globe and Rome, in which the process was most explicitly structured according to progressive inquiry (see Table 4), the collaboration was also deliberately supported by organizing the class in small groups. In the Globe design, the formation of groups was based on the students' research interests and topics of wonderment; the groups resembled authentic scientific research groups that had a common inquiry goal to pursue. In the Rome design, the teacher appears to have applied an approach similar to the Jigsaw method, developed in the framework of co-operative learning (Aronson, Blaney, Srephan, Sikes, & Snapp, 1978), using 'expert groups' and groups for sharing expertise in successive phases.

In most of the secondary school level designs, the organization of collaboration was not so systematic as in the primary school level designs, and the teachers were rather critical about the success of collaboration. Certain patterns can be seen by combining the results in Table 5 and the teachers' interview answers. In those settings (e.g., in Matrix, and Read & Write), in which the goal of students' collective activity was just to conduct open discussion and brainstorming in the discourse areas, the teachers reported that it succeeded well and students participated actively (e.g., "The discussion threads did not have time to grow very long, but there was genuine discussion, and everybody had a feeling for collectiveness. They formed a learning community" or "I was surprised that even though there were students from two schools, they commented the ideas of those students that were not in the same group"). But in those settings (e.g., in Culture, Kalevala, Youth, and Financing), in which the students were expected to more systematically contribute to collaborative inquiry, or to the creation of a joint knowledge product, the collaboration did not work out as the teachers had hoped (e.g., "The common part succeeded very well. The students had also good collaboration when they were brainstorming the group works, but not anymore in the commenting phase" or "Students announced invitations for collaboration in net, but they were not replied very eagerly. There were several messages that 'We have a similar topic', but they were not replied, although I encouraged the students to collaborate. But it was obviously a strange situation. Yet, the students replied to each others' notes and commented them

Table 6
Different types of artifacts produced by the students and the teachers in each experiment

Unit	Students *N*	Student notes *f*	Student documents *f*	Student links *f*	Teacher notes *f*	Teacher documents *f*	Teacher links *f*	Artifacts in all *f*
Globe[a]	28 + 27	790[b]	107	4	63[c]	3[c]	9	976
Rome	28	621[b]	90	1	20[c]	2[c]	2[c]	736
Kalevala	30	186	26	0	25	1	3	241
Culture	15	287	1[c]	0	76[b]	2	3	369
Youth	23	154	9[c]	6[b]	46[b]	4	5	224
Financing[a]	14, 19	113[c]	63[b]	6[b]	26	10	0	218
Matrix	32	152	0[c]	0	22	3	10[b]	187
R&W[a]	6, 13	97[c]	9	0	24	57[b]	13[b]	200
Total		2400	305	17	302	82	45	3151

Note: Significance tests are based on hyper-geometric probability estimations (see Bergman and El-Khouri, 1987).
[a] The data of the two student groups are combined.
[b] Observed frequency larger than expected by chance alone ($p < 0.001$).
[c] Observed frequency smaller than expected by chance alone ($p < 0.001$).

actively, but concrete collaboration actualized only in a few groups''). The teachers concluded that they should have paid more attention to the organization and fostering of collective activity (e.g., ''I think that it did not succeed as well as it should have. The students concentrated mostly on their own affairs. Actually I stopped the process in one stage, and we distributed the responsibilities so that everybody comments somebody else's work. But, on my opinion, they did not produce so many comments or advise to others. One should pay even more attention to emphasizing collaboration'' or ''What I would do differently, if we make a new project with other school, I would make the students do still more joint work'').

In parallel with the collective work, the primary teachers (in the Globe and Rome designs) also set up private discourse areas for each student for personal feedback, and the students had the task to produce an individual final report as a result of their work, although they otherwise worked in groups. The same trend of mixing collective and individual work is present in most of the secondary level projects: in addition to the common discourse in Synergeia, each student was expected to make an individual final product or accomplish certain individual tasks during the process. The Financing design, carried out in a high school course, was the only one in which the students were expected to create collective research reports in groups. According to the teacher's description, the same purpose was originally also in the Culture design, but the distance work made the challenge difficult to achieve, and, eventually, many students did the final work alone.

4.3. Using the web-based collaborative learning environment for sharing knowledge

The use of collaborative technology in the designs was evaluated by investigating the knowledge produced to the collective databases by the students and the teachers. The first examined aspect was, whether the pedagogical designs differed from each other in emphasizing the use of discourse areas, or sharing of documents and links. In Table 6 are presented the proportions of various types of artifacts (notes, documents and links) produced by the students and the teachers

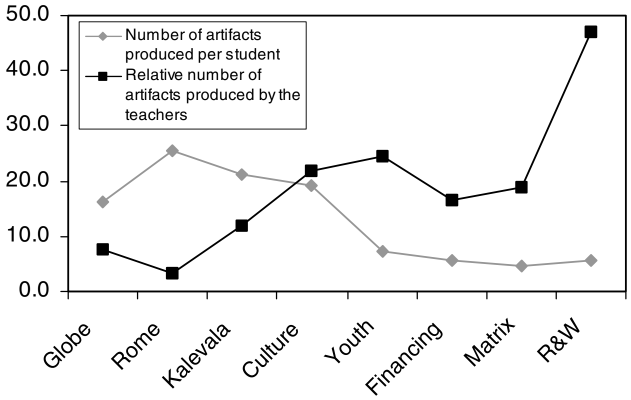

Fig. 1. Number of artifacts produced per student, and relative number of artifacts produced by the teacher of all artifacts in the database in each project.

to the database in each design. According to χ^2-test there was a significant difference between the groups, χ^2 (35, $N = 3151$) = 1010.49, $p < 0.001$. Cell-specific exact tests (Bergman & El-Khouri, 1987) were carried out in order to examine whether the observed frequencies in each cell deviated from what could be expected by chance alone.

Based on the results in Table 6, some conclusions can be made about the differing emphasis of the CLE's role in the designs. It is noteworthy that in the primary level designs (Globe and Rome), which mostly followed the logic of progressive inquiry according to the other analyses, the tools of the CLE appears to have been used in a versatile way: The discourse areas were in frequent use, but the system was also used by the students for sharing documents and links. In the Culture and Matrix designs, the CLE was used only for threaded discourse, whereas in the Financing design, the work concentrated mostly on producing and sharing documents and links. In the Read & Write design, the high school project in special education, the teacher herself delivered a great deal of learning materials and tasks for the students through the database in the form of documents and links.

The students' and the teachers' relative activity in the knowledge production process was also examined by comparing the average number of artifacts (notes, documents and links) produced per student to the relative proportion of the teachers' artifacts in the database in each design (Fig. 1). Fig. 1 reveals that the teachers' contribution in producing knowledge to the database is relatively greater in most of the secondary level designs than in primary level designs (Globe and Rome). In the primary level designs, the students were very active producers of knowledge, whereas especially in the high school designs (Financing, Matrix, and Read & Write), the students did not produce, on average, many artifacts. In the Read & Write design, the high school project in special education, the relative proportion of knowledge produced by the teacher to the database was almost 50%.

5. Conclusions and discussion

The purpose of the present study was to evaluate the Finnish teachers' designs, their implementations of technology-supported collective inquiry in special units, in primary and secondary classrooms. A focus was on the challenges encountered in classroom contexts following standard curriculum. As Leinhardt, Young, and Merriman (1995) stated, it is difficult to integrate theoretical knowledge about learning, and practical professional knowledge about teaching.

5.1. Epistemic nature of the pedagogical designs

When implementing research-like inquiry as a working method in educational settings, the teacher does not deliver knowledge, or give students highly-defined tasks and assignments, but provides context and conditions for the students' own inquiry, as well as online support and facilitation. The teachers' role is to model and structure the process to help students to learn strategies and skills that are essential in purposeful inquiry. The results of the present study indicate that most of the teachers aimed at promoting purposeful inquiry in their pedagogical designs, but they did not necessarily know good methods and practices for structuring and scaffolding students' inquiry efforts. The primary school teachers rather cleverly built up supporting structures in the students' inquiry process, whereas the secondary school the teachers relied a great deal on the students' self-regulation. Perhaps they initially believed that secondary level students already have the necessary skills for inquiry, and noticed the need for structuring only during the process.

Some teachers tended to give up the goals for accomplishing progressive inquiry, and turned back to conventional school tasks and assignments defined more strictly by the teacher. In such tasks, the object of activity is the accomplishment of a task rather than the advancement of ideas, which changes the epistemic nature of the activity (Scardamalia, 2002). Veermans and Järvelä (2004) reported parallel findings from a primary classroom conducting progressive inquiry: The teacher appeared to lower the working norms of a poorly achieving student, without trying to find ways for more coherent and useful support to help that student achieve the higher-level goals. The teachers obviously need support and examples of advanced practices to develop their expertise in scaffolding and promoting purposeful inquiry. There is also a more substantial challenge for teachers concerning the contradiction between the new inquiry-based conceptions of learning and knowledge, and the demands of prevailing school curriculum (Salomon, 2002).

5.2. Social nature of the pedagogical designs

In CLE, the threaded discourse areas were experienced by the teachers as an especially valuable new possibility to promote collective working practices in schools, and many teachers reported how eagerly the students participated in the interaction by reading and commenting each other's ideas. There is obviously a demand for such collaborative tools in schools. However, the most difficult objective appears to have been, according to the analyses and the teachers' opinions, to induce the students to enter into 'serious' efforts for advancing collective understanding and elaborating common knowledge objects. Actually, the social arrangements in many of the designs still supported rather individualistic ways of working: The students were assigned to make an individual final product along with the common discourse. Only in one high school project, were the student groups given an explicit assignment to produce a collective research report. Olson (2003) stated that both collective and individual responsibility and accountability are important elements in collaborative learning. Individual accountability is needed because cultural knowledge and learning become transformed to individual competence only through an individual participant's own extended efforts (Hakkarainen, 2003b). However, collective accountability, or collective cognitive responsibility, as Scardamalia (2002) defined it, develops only if the students are expected and guided to take it, and the collective activity is explicitly directed towards the development of shared knowledge objects. It may be stated that the best pedagogical designs for collaborative learning build up social infrastructure that promotes both collective and individual accountability.

5.3. Utilizing the affordances of the technical infrastructure

Both the teachers and the students appear to have been competent enough in using the web-based collaborative learning environment, even though the Synergeia software was only a test version with some technical problems. Nevertheless, there were substantial differences in the ways of using the affordances of the technology in separate cases. Yet the differences seem related to the design of the educational setting more than, for instance, to the age or technical competence of the participants. Bereiter and Scardamalia (2003) argued that threaded discourse forums do not, as such, support real knowledge building because they do not enable easy revision and integration of previously recorded ideas. The results of the database analysis in the investigated designs revealed that in some, the CLE was used in very versatile way for collective knowledge advancement, combining the use of multiple working spaces, threaded discourse areas, document sharing and commenting, and links to Web sources. The design of activities in those cases likely supported advanced ways of working with knowledge, but more detailed analysis of the content and quality of the knowledge produced in the databases is required for solid conclusions.

5.4. Challenges for the future

According to the results, the two primary school projects (conducted in three classrooms) were successful and sophisticated in many ways: They were structured for supporting inquiry strategies, organized explicitly for collaborative activity, emphasized students' knowledge production, and applied the CLE for sharing knowledge sources, ideas and documents. Also, the secondary school designs were innovative and ambitious in many ways, but they comprised more features resembling traditional school tasks and activities. In Finland, new pedagogical innovations appear to be, in general, much easier to implement in primary schools (which includes grades 1–6) because the same teacher teaches almost all lessons to the class, and can design the curriculum and activities flexibly. In addition, perhaps the idea of letting the students practice new, challenging ways of working is more natural in primary education, where students are still very young, and the teachers cannot presume that they already have the necessary skills. In secondary education, different teachers teach separate subject domains, usually in 45-min periods; the curriculum is much tighter, and the demands for efficiency, stronger. In the present study, it was important to also investigate the implementation of the pedagogical innovation in upper-secondary schools because, according to the experiences of the present researchers, it is very difficult to persuade upper-secondary teachers to participate in such development projects. The pressures of the national, final, matriculation examination at the end of upper-secondary school appear to be so dominant in the curriculum goals that the teachers do not want to spend valuable teaching time for experiments. In general, students should have a possibility to practice new working methods in all school levels; growing up to a knowledge building culture has to happen gradually throughout the whole schooling period (Lakkala et al., 2002).

It should be kept in mind that the investigated teachers were faced with a very demanding task, although they were experienced in using computers in their teaching: new technological tools, new pedagogical models, emphasis on collaboration instead of students' individual achievements, and also the challenges of interacting with the other teachers and the researchers in the development project. Taking all that into account, the teachers managed very well. In the long run, the goal should be permanent change in the learning culture, not just in temporary development projects. Therefore, one important research objective for the future is to follow how sustained these changes are in the teachers' regular classroom practice.

In the present study, various data sources and analysis methods were combined to examine the teachers' pedagogical designs. As Windschitl (1998) pointed out, qualitative research approaches are valuable in investigating phenomena in novel fields, such as the promotion of technology-supported collective inquiry learning. New research methods, besides controlled experiments, are required to study complex learning environments in real educational settings (Winn, 2002). The present research produced applicable frameworks for describing and understanding the pedagogical design challenges in collaborative settings, but the cultivation of the research methods should continue. A very important direction for further methodological development would be to find methods to investigate how the pedagogical design of collective inquiry practices influences students' engagement and learning.

For educators and teachers, a valuable practical tool would be a design framework that scaffolds the pedagogical design process when planning collective inquiry practices for various educational settings. Such framework could help the design process, and also the evaluation of the implementations by explicating the crucial elements in the design, and, through examples, furnishing guidelines for critical design decisions.

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