Abstract

In the modern pedagogical practices based on socio-cultural approaches on learning, students are seen as active agents who share ideas, solve open-ended problems, use various information sources, and create new knowledge together. Teachers, who want to implement such practices in their classrooms, often face with the demands of changing their traditional ways of designing teaching. Classic models of instructional design are not very applicable to collaborative learning because they mainly concentrate on individual processes of learning and are based on the strict pre-structuring of content and activities. The pedagogical design of collaborative learning is more indirect, focusing on organizing the preconditions for the eligible collaborative activity but not causally determining the learning results. Building on such views, the present paper introduces a framework of pedagogical infrastructures, consisting of technical, social, epistemological and cognitive components; to be used in designing and analysing technology enhanced collaborative learning units. Also the role of e-learning content in such educational settings is discussed through this presented framework.

Keywords: Collaborative, Learning, Pedagogy, Design, Infrastructure

Introduction

Contemporary socio-cultural theories of learning emphasize that various social and cultural factors should, especially, be taken into account in explaining learning and developing new pedagogical approaches (Bruner, 1996; Lave & Wenger, 1991; Vygotsky, 1978) Learning is not just a cognitive issue but also a matter of participating in cultural practices (Sfard, 1998) and creating new knowledge and ideas of value to a community (Paavola & Hakkarainen, 2005; Scardamalia & Bereiter, 2003). The aim of present-day schooling is to support the development of students’ competences and skills for the emergent knowledge society through appropriate educational practices, rather than mere establishment of content mastery in some basic subject domains. Pedagogical practices that are regarded to support the development of such competences include student ownership and active involvement; collaboration between participants; activities of searching, sharing and elaborating knowledge; working with authentic, ill-defined problems; critical reflection on one’s own activity; and the teacher’s changed role from delivering knowledge to organizing, guiding and assessing students (Ilomäki, Lakkala & Paavola, 2006; Kozma, 2003).

Modern information and communication technology presents new possibilities but also new challenges for understanding learning, collaboration, and working with knowledge. Technology
enables new kinds of practices, but how should technology be integrated to serve advanced ways of learning? As McCormick and Li (2006) stated, the effects of technology depend not only on the tools but above all on the pedagogical implementation; a successful application of technology in education always means that many systemic changes in the whole activity environment also take place. In such transformation, crucial element is the teachers' pedagogical competence in integrating technology into the educational practice and designing their teaching in a new way (Smeets and Mooij, 2001). As stated in some recent research publications (Lakkala, Lallimo & Hakkaraainen, 2005; Scardamalia & Bereiter, 2006; Strijbos, Martens & Jochems, 2004), traditional instructional design models or ways of planning teaching are necessarily not very useful for organizing educational settings that are based on emergent collaborative processes and student-directed inquiry. The present paper examines this challenge of re-conceptualizing the demands for educational design in technology enhanced collaborative learning.

Pitfalls of classic instructional design models for designing collaborative learning

The design of educational settings and learning materials has dominantly followed the models of instructional design, which are based on learning research fed by cognitive psychology (Gagne and Merrill, 1990; Häkkinen, 2002). In those approaches, the learning content is rather systematically determined and pre-structured, and learners’ activity is predefined to follow specific, uniform sequences. In recent studies, the instructional design models are revised to better adapt in the design of complex, authentic tasks which are believed to result in qualitatively better learning outcomes. For instance, Merriënboer, Kirschner and Kester (2003) suggest such design strategies as scaffolding whole-task practice (sequencing simple-to-complex classes of equivalent tasks; using worked-out examples), and just-in-time information presentation (linking supportive information to task classes; presenting procedural information precisely when it is needed during task performance). However, these strategies still examine the design mainly from the individual students’ viewpoint and in situations where the learning of certain content is the primary aim.

In the socio-cultural paradigm, human activities in general are seen as socially mediated, which entails that also learning is embedded in the social processes of knowledge construction rather than being an individual venture (Vygotsky, 1978). The rise of collaborative learning practices as a consequence of this socio-cultural paradigm shift has challenges the prevailing detailed and strictly structured ways of designing learning and teaching (Lowyck & Pöysä, 2001; Palincsar & Herrenkohl, 2002) because the processes and outcomes emerging in a collaborative learning setting are (and should be) strongly shaped by the joint activity and interaction of the participants themselves and cannot be fully designed in advance (Dillenbourg, 2002). And yet, many practitioners and researchers have also witnessed that totally free, unguided or unstructured collaboration does not necessarily result in productive activity or learning (Kreijns, Kirschner & Jochems, 2003; Winn, 2002).

Some researchers have suggested an intermediate solution between classic instructional design and collaborative learning approach with the notion of scripts. Instead of strict pre-structuring of tasks, the learner groups could be provided with scripts that guide students’ collaborative activity to make it more productive and effective for learning. Dillenbourg (2002) defined scripts as a rather detailed set of guidelines, rules and structured tools describing how the group members should interact, how they should collaborate and how they should solve the problem. For example, Weinberger and colleagues (2005) designed epistemic scripts to facilitate students’ knowledge-construction activities and social scripts to structure the interaction of learners in a collaborative learning setting. This design approach takes into account the social dimension of learning but it is still focused on
supporting and stimulating individual learners’ content acquisition via, sometimes arbitrary and superficial, structuring of collaborative activity. It may result in disturbing natural interaction and problem solving processes and may lead to introduce fake collaboration (Dillenburg, 2002). In addition, scripts are not the all-round solution to the design of educational settings.

**Designing distributed scaffolding for collaborative learning**

Another approach that is worth mentioning, when discussing how to understand the challenges of designing complex, technology-enhanced collaborative learning settings, is the notion of distributed scaffolding, introduced by Puntambecar and Kolodner (2005). They proposed that the support for students in a complex classroom community needs to be distributed, in a complementary way, across various tools and agents constituting students’ learning environment; such as instructional materials, task structures, social arrangements, technological tools, as well as teacher guidance. Examples of the elements that could be designed to actualize such distributed scaffolding are e.g. certain kind of task sequencing, templates and prompts embedded in tools, and timely teacher interventions.

Distributed scaffolding sounds like a promising idea for examining the support that should be provided for collaborative learning, but perhaps the concept on scaffolding is too narrow a notion to describe the whole design challenge. As Pea (2004) argued, the meaning of the scaffolding concept should not be widened to mean all kinds of structures and elements in a learning setting. Originally, it described the adapted guidance that a more competent adult provided to help an individual learner accomplish a problem-solving task that was otherwise beyond his or her skill, and the support was given only for as long as needed, until independent performance was achieved (Wood, Bruner & Ross, 1976). Educational design includes much more than only the design of temporary support that the learners need in specific tasks and situations. For instance, some functionalities in technological tools that are in students’ use, do not so much ‘scaffold’ the cognitive or collaborative learning temporarily, as provide cultural tools that are an essential part of the collaborative learning practice or working context. It seems that a more general approach to conceptualize the design of technology-enhanced collaborative learning is needed.

**Perceiving pedagogical design as building of appropriate infrastructures**

Jones, Dirckinck-Holmfeld and Lindström (2006) stated that the actualization of computer-supported collaborative learning settings is based on indirect design, in which the providing of technology creates affordances for collaborative learning in relationship with the active agents and other features of the situation. Thus, the pedagogical design of technology-enhanced collaborative learning could be seen more as providing basic supporting structures that offer affordances and foster the eligible learning activity but do not prescribe the exact activities or outcomes. Building on such views and previous studies (e.g., Bielaczyc, 2001; Guribye, 2005; Lakkala, Lallimo, & Hakkarainen, 2005; Lipponen & Lallimo, 2004; Paavola, Lipponen, & Hakkarainen, 2002), we have started to use the notion pedagogical infrastructures to illustrate how the pedagogical design of collaborative learning practices resembles the construction of basic physical infrastructure to support smooth and effective functioning of people’s daily activities (Star, 1999).

Bielaczyc (2001, 2006) introduced the notion of social infrastructure associated with designing learning environments. She stated that characteristic of successful technology-enhanced collaborative learning is that an appropriate social infrastructure is built to support the use of
technology; such as classroom culture, working practices and the usage of the possibilities of the Web-based tools for collaboration. For instance, there is a difference in the social infrastructure of a course where students are only generally encouraged to comment on each other in joint discussions and a course where the commenting responsibilities are explicitly arranged, applying certain rules and team structure; or in a course where each team is working on their own task in closed areas, or where everything is deliberately shared between all course participants. Also other researchers have stressed the importance of systematic and adequate structuring of social practices in technology-enhanced collaborative learning (Akar et al., 2004; Dillenbourg, 2002; Wegerif, 1998).

In our research group, we have proposed to broaden Bielaczyc’s suggestion by considering more analytic set of infrastructures to structure and enlighten the designing of educational settings for collaborative learning practices. Paavola, Lipponen and Hakkarainen (2002) stated that the practices in education should also be examined from the viewpoint of the conception of knowledge that the practices reflect. They suggested that besides technical and social infrastructure, an educational setting should be shaped by an epistemological infrastructure, involving, e.g., the nature of knowledge sources used; students’, teachers’, and content materials’ role while creating and sharing knowledge; the emphasis on knowledge-creating inquiry in the tasks and assignments; in general such infrastructure to be characterized in the way knowledge is understood or treated and the processes of inquiry applied in a given educational setting. For example, there is a very different epistemological infrastructure in a distance learning course where studying is organized for learning certain parts of subject matter from a tutorial, and a course where students carry out a piece of research based on real life problems, also using authentic information sources provided by the expert of the field. In educational practices aiming at collaborative knowledge creation, the knowledge that is associated with the process does not merely represent subject domain content that the individual students should try to internalize; rather, knowledge should be a primary object of joint development work (Paavola, Lipponen & Hakkarainen, 2004; Bereiter, 2002).

In addition to providing students with relevant technological tools (technical infrastructure), promoting them to collaborate effectively (social infrastructure), and directing them to treat knowledge as something that can be shared and developed (epistemological infrastructure), we propose that educational settings should also include an appropriate cognitive infrastructure, ensuring that students get a conscious understanding of the working strategies and gradually learn to work independently in an expert-like way (Muukkonen et al., in press). This relates to the expectations for education that stem from beliefs that the future knowledge society requires not only content mastery but competencies of working with knowledge (Scardamalia and Bereiter, 2003; Hakkarainen et al., 2004). Educational setting could support the development of students’ metalevel awareness of the critical processes and strategies, e.g., by making the process visible, modeling and structuring the relevant phases of the process or promoting deliberate reflective self-evaluation (Choi et al., 2005; Krajcik et al., 2000; White and Fredriksen, 2000). For instance, project-based work can succeed in a certain level if you just give the project task to a group of learners, but if you provide them with a good project model that helps the group to organize their work and carry out the critical procedures, the outcomes are probably much better and the process more effective. With the conceptual support of the model, the students hopefully learn to carry out next projects more effectively without so much extra help and drawbacks. Such support can gradually be withdrawn from the educational situation when students have internalized the effective ways for collaboration and knowledge work. Providing students with concrete scripts (Dillenbourg, 2002), discussed in the previous chapter, can be regarded as an example of building cognitive infrastructure for collaborative learning.
I suggest that this kind of framework of pedagogical infrastructures, consisting of technical, social, epistemological and cognitive infrastructure, can be used to classify, design and evaluate the elements of educational settings based on technology-enhanced collaborative learning. The separate infrastructures exist in parallel, and in a successful educational setting all aspects are taking care of and designed to foster collaborative knowledge creation: there is deliberate collaboration built in the tasks, technology works and is used as it should, the object of students’ activity is genuine working with knowledge (not just internalizing certain content), and students' autonomy and the development of skills are supported by explicit cognitive modeling of expert-like practices. In the following chapter is a case example where one elementary school history project is examined through the framework.

Case: Progressive inquiry in elementary school history

General teaching arrangements in the unit

The unit, titled ‘10 secrets’, was carried out in a Finnish test site during the EU-funded ITOCLE-project (see http://www.euro-cscl.org/site/itcole; Ligorio & Veermans, 2005). The participants were on the 5th grade in a Finnish elementary school, altogether 56 students from two different classes, and two teachers. The project was carried out during nine weeks, in history and Finnish language lessons. The work consisted of two to four hours per week in a computer lab (with 17 computers), and two to four hours per week in a regular classroom (with one computer) or in the school library (with 12 computers). Two teachers designed the project together, but each class had its own lessons. The students could visit the working space of the other class in the virtual learning environment and both teachers guided both classes there.

Pedagogical approach

The pedagogical approach that was incorporated into the project was based on the model of Progressive Inquiry (Hakkarainen, 2003). In progressive inquiry, the teacher creates a context for inquiry by presenting a multidisciplinary approach to theoretical or real-life phenomena, after which the students start defining their own questions and intuitive working theories. Students’ questions and explanations are shared and evaluated together, which directs the utilization of authoritative information sources and iterative elaboration of subordinate study questions and more advanced theories, explanations and writings. Progressive Inquiry was illustrated for the students by a graph presenting the elements of the process (Creating the context, Setting up research questions, etc.) as an iterative, cyclic continuum.

Collaborative technology and content materials used

The Web-based learning environment used in the unit was FLE3 (Future Learning Environments; http://fle3.uiah.fi). FLE3 consists of a user’s WebTop (virtual desktop) and a Knowledge Building module (Leinonen et al., 2003). Users in the same course can visit each other’s WebTop and see its content. Also the shared course folder for each course is visible in each participant’s WebTop. The Knowledge Building module provides a shared space, in the form of threaded discourse forums, for sharing and elaborating problem definitions, explanations and theories together by all the participants. The KB discourse is scaffolded and structured by asking a user to categorize each note by choosing a knowledge type (Problem, Working theory, Deepening knowledge, Comment, Metacomment or Summary) for the posting, corresponding to the progressive inquiry model.
Content materials used by the students were

- stories and biographies of historical explorers;
- a video about historical discovery;
- ten historical pictures;
- historical books available in the classrooms and school library; and
- authentic knowledge sources in the Web.

**Organization of the working process**

The main idea of the *10 secrets* unit was to interpret historical pictures from different time periods to understand history. The context for the project was created by familiarizing the students with some stories and biographies of historical explorers. A video was shown in order to introduce students to the working practices of historians. Further, the principles and working procedures of progressive inquiry were described and discussed at the beginning of the project.

The teachers had uploaded, in FLE3, 10 pictures (or “10 secrets”) from different time periods; e.g. a picture of a cave painting or the statues in Easter Island. The students chose one picture for a starting point for their project; their task was to figure out the mystery of the picture. The teachers gave some written guidelines and guiding questions for the students to start their inquiry (e.g., From what time period the picture could be? Who could the people in the picture be?). The students formed small research groups, based on the picture they selected to investigate. Both of the classes had their own course area in FLE3, but all the students were invited in both of the courses. In two groups, there were students from both classes.

First, the students created their own explanation of the picture in FLE3’s Knowledge Building area. Then they commented on each other’s explanations, searched for deepening information from books and from the Web, and developed new and more detailed explanations together. Teachers guided the group’s process in the classroom and in the technology-mediated discourse. At the end of the project, the student wrote self-evaluation memos in the course folder in FLE3, according to the guiding questions given by the teacher. The students also wrote historical stories in groups and posted them to the course folder. The last part of the project was a face-to-face classroom discussion where the students evaluated the historical stories they had written.

*The analysis of the pedagogical infrastructures of the unit*

In the following Table 1, the design features of the *10 secrets* unit are described through the framework of pedagogical infrastructures.
Table 1. Examples of some design features in the *10 secrets* unit.

<table>
<thead>
<tr>
<th>Infra-structure</th>
<th>Description of the feature</th>
<th>Actualization in the unit</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Technical</strong></td>
<td>Providing of technology and technical advice for the students</td>
<td>FLE3 in use as a web-based tool for collaborative work. Text editor available for writing stories. Access to technology and guidance available in all lessons.</td>
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<td></td>
<td>The appropriateness of tools for the desired activity.</td>
<td>FLE3 was especially designed to support Progressive Inquiry practices (shared discourse forums with built-in inquiry scaffolds, personal but open WebTops).</td>
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<td></td>
<td>Organizing the use of technology</td>
<td>Technology was used in the school premises, with varying number of computers; the students had to take turns in using them.</td>
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<tr>
<td><strong>Social</strong></td>
<td>The explicit arrangements to advance and organize students’ collaboration and interaction.</td>
<td>Students’ collaboration was systematic organized through small groups that were founded according to students’ choices of the historical pictures.</td>
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<tr>
<td></td>
<td>Openness and sharing of the process and outcomes.</td>
<td>All materials and the whole working process were openly shared between all participants through FLE3. The inquiry task and stories were done in groups, only the final self-reflection was written individually.</td>
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<td></td>
<td>The integration of face-to-face and technology-mediated activity.</td>
<td>All activity, also through the technology, took place in classrooms; no virtual working periods. Some groups consisted of students from two different classes; those students communicated only through technology with each other.</td>
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<td><strong>Epistemological</strong></td>
<td>The conception of knowledge that the practices reflect.</td>
<td>The practices emphasized that learning to understand the nature of history as a science requires participation in real research activities. No rote learning, e.g. no final exam based on assessing memorization.</td>
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<td></td>
<td>The nature of knowledge advancement.</td>
<td>The course task was to accomplish question-driven inquiry, based on the students’ own choices of the historical pictures.</td>
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<td></td>
<td>The role and nature of knowledge sources used.</td>
<td>Authentic historical pictures as a starting point of students’ inquiry. Rich variety of knowledge sources available for students. Orientation materials chosen by the teachers beforehand. The orientation materials presented authentic expert practices in the field.</td>
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<tr>
<td></td>
<td>Students’ and teachers’ role in creating and sharing knowledge.</td>
<td>The teachers provided background materials; otherwise the student groups sought and produced knowledge themselves.</td>
</tr>
<tr>
<td><strong>Cognitive</strong></td>
<td>Explicit modeling of the working strategies and practices.</td>
<td>Modeling the inquiry strategies by presenting the heuristic model of Progressive Inquiry as a graph.</td>
</tr>
<tr>
<td></td>
<td>Guidance provided for the students.</td>
<td>Written guidelines for the working practices of PI in the first lesson. Teachers’ guidance available in all lessons and through the technology.</td>
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<tr>
<td></td>
<td>Methods used to promote metacognitive thinking and meta-level reflection of the inquiry process and practices.</td>
<td>Reflection on the groups’ inquiry throughout the process; joint face-to-face evaluation discussion in the last lesson; pre-defined open-ended questions for self-reflection provided for the students to be answered in FLE3.</td>
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<tr>
<td></td>
<td>Cognitive scaffolding and support for collaborative inquiry embedded in tools and technology.</td>
<td>Built-in inquiry scaffolds (Problem, Own explanation etc.) in the knowledge building areas of FLE3 “forced” students to structure there discourse.</td>
</tr>
</tbody>
</table>

Although the introduced pedagogical infrastructures are still rather artificial and abstract, I believe that such approach is helpful in focusing the design efforts of technology-enhanced collaborative learning in some critical and fundamental aspects. They are also generic enough to be applied for designing, analysing and comparing various kinds of educational settings (Lakkala et al., 2005).
What is the role of digital content materials in technology-enhanced collaborative learning?

If we accept that the desirable pedagogical practices consist of tasks where students solve authentic and open-ended problems together, using modern web-based technology and searching for knowledge from various information sources, how should we then define the role of content materials? In such practices, almost anything can be used to serve the collaborative process, which makes it difficult to draw boundaries around those resources that are ‘learning materials’ and those that are not. Is there anymore a need for materials and resources that have been specifically produced for teaching and learning?

During the past few years, one often discusses issue in the field of educational technology has been the approach of learning objects (LOs), which means separate, relatively concise digital learning resources shared through the Internet and reused in multiple educational contexts to support learning (Nurmi & Jakkola, 2006). In the learning objects approach, I especially like the basic principle that any one material does not fulfil the demands of a certain educational setting, but the materials are just sketches, elements or building blocks for the process, and the teacher’s (or sometimes students’) responsibility is to design and organize the educational setting and collect the learning objects that are useful for the goals of that setting. Various kinds of materials can be valuable, depending on the situation and the phase of the process, but the educators have to be aware of the possibilities and constraints that the pedagogical type of the material has for learning (e.g., drill-and-practice type material is for rehearsing already learnt facts but it is not very suitable for developing open-ended problem-solving skills). The LO approach is totally different than the older 'Computer-Aided Instruction' approach, based on instructional design models, where one large material was supposed to teach everything needed in a certain setting. On my opinion, the basic principle of the LO approach is well in line with the nature and demands of educational practices that are based on socio-cultural approaches on learning.

Looking through the specified framework of pedagogical infrastructures, the main role of content materials seems to be to contribute to the building of the epistemological infrastructure in the educational setting. Although there is a lot of information available in the Internet, the use of authentic information sources can sometimes be problematic in a learning situation. For instance, there might not be enough or appropriate materials available for specific purposes and authentic sources are often too difficult to understand at least for beginners or younger students. However, the option cannot be to produce too narrow ‘schoolbook like’ content materials that give a superficial or simplified view of the phenomena under study. Content material that creates, on its part, a sophisticated and advanced epistemological infrastructure, should represent epistemological affordances that promote expert-like working with knowledge; e.g. to give a possibility to deal with the complexity of the content; provide background information, contradicting views and evidence for the theories and facts; and give multiple representations and contextual features to the phenomena (Ilomäki et al., 2003, 2006). This kind of content material can be, for example, a rich glossary or a simulation combined with theoretical knowledge.

In the EU-funded CELEBRATE project (see http://celebrate.eun.org/eun.org2/eun/en/index_celebrate.cfm), we conducted a multiple case study where four Finnish teachers implemented specific digital learning materials in classroom units representing ‘advanced’ pedagogy (Ilomäki et al., 2006). The results showed that most useful and versatile content materials where such that were rich information sources, exploratory-type exercises, or open activities, which can be used in multiple ways. One good example was a Finnish
exploratory-type learning object titled “A healthy meal” (see http://www.edu.fi/oppimateriaalit/healthy_meal/) or “Terveellinen ateria” in Finnish (see http://www.edu.fi/oppimateriaalit/terveellinenateria/). It was originally planned for vocational education (for the students of catering), but in the CELEBRATE case studies, the Finnish version was used with elementary level students to reflect on their own eating habits, and the English version was used with lower secondary level students to study food and nutrition related vocabulary in English language lessons.

Specific learning materials can also have a role in building the social and cognitive infrastructures of an educational learning setting. One type of learning materials might be separate ‘content-independent’ materials, which are tools, process descriptions or templates of some kind that provide strategic support (for students and/or for teachers) in the expert-like working processes and pedagogical models. As Ilomäki and colleagues (2003) suggested, such materials could include meta-knowledge of the basic principles, steps or phases of the process; and cognitive guidelines, hints and checklists for actualising them. Phases could be ”meta-explained” by telling what to do, why to do it, and how to do it; including theoretical knowledge (written in appropriate level) of the pedagogical model itself, its goals and implications for learning, in order to add students’ metalevel understanding of the learning and working process. For example, designing generic process materials for broadly known, established pedagogical models - such as problem-based learning, progressive inquiry or project-based learning - can serve wide audience and could be used in various educational settings, in spite of the subject domain or learning setting.

References


