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2010

Lakkala, M, Ilomäki, L & Kosonen, K 2010, From instructional design to setting up pedagogical infrastructures : Designing technology-enhanced knowledge creation. in B Ertl (ed.), Technologies and Practices for Constructing Knowledge in Online Environments : Advancements in Learning. Information Science Reference, Hershey, PA, pp. 169–185.

http://hdl.handle.net/10138/567993

acceptedVersion

Lakkala, M., Ilomäki, L. & Kosonen, K. (2010). From instructional design to setting up pedagogical infrastructures: Designing technology-enhanced knowledge creation. In B. Ertl (Ed.), *Technologies and Practices for Constructing Knowledge in Online Environments: Advancements in Learning* (pp. 169–185). New York: Information Science Reference.

From Instructional Design to Setting Up Pedagogical Infrastructures: Designing Technology-Enhanced Knowledge Creation

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ABSTRACT

Changes in society and working life have led educationists to propose that educational practices should pay special attention to advancing skills for knowledge creation, collaboration, and expert-like working with knowledge supported by modern technology. Classic models of instructional design mainly concentrate on individual content learning and are based on the strict pre-structuring of activities. The pedagogical design of collaborative knowledge construction is more indirect, focusing on establishing the underlying conditions in the learning environment to enhance desired practices. This creates new challenges for pedagogical design. Building on such views, a *pedagogical infrastructure framework*, including technical, social, epistemological, and cognitive components, is introduced as a conceptual tool to be used in evaluating the implementations of technology-enhanced collaborative knowledge practices in education. Three course examples are described using the introduced framework to demonstrate its applicability for examining pedagogical designs.

Keywords: Socio-Cultural Paradigm, Knowledge Creation, Knowledge Building, Collaborative Learning, Technology-Enhanced Learning, Web-based education, Scaffolding, Distributed Scaffolding, Pedagogy, Pedagogical Infrastructure, Social Infrastructure, Epistemological Infrastructure, Cognitive Infrastructure, Instructional Design, Design Principles

INTRODUCTION

A widely experienced concern in western societies is how to prepare present-day students to cope with the demands of the knowledge-based society and their future working lives. An obvious educational challenge is the need to train citizens to use modern information and communication technologies that constitute the most visible part of the knowledge society. It appears, however, that the skills for using the new technology or basic information skills are not enough, and that people need more advanced skills for working with knowledge, using it meaningfully in different contexts and collaborating with others. Educational experts are proposing that educational practices should pay special attention to improving competencies necessary for expert-like knowledge work and co-construction of knowledge instead of mere content mastery in specific subject domains (Bereiter, 2002; Paavola & Hakkarainen, 2005). These viewpoints relate to the increasing interest in the *socio-cultural paradigm*, in which human activities in general are seen as socially mediated, which entails that learning is also regarded as embedded in social processes rather than being an individual venture (Vygotsky, 1978; Jonassen & Land, 2000).

Within current educational literature, the pedagogical practices that researchers recommend and emphasize as important, have very similar characteristics to each other. These characteristics typically include solving of authentic ill-defined problems, usage of various knowledge sources, collaboration in groups, usage of web-based technology for collaboration, the creation of new knowledge and concrete products as a result of the working process, and critical self-reflection (see, e.g., Scardamalia 2002; Winn 2002; Kozma, 2003; Ilomäki, Lakkala, & Paavola, 2006). Paavola and Hakkarainen (2005) suggested that such viewpoints represent an emerging epistemological approach to learning, which they call the *knowledge creation metaphor*. This suggestion extends the well-known idea of two metaphors of learning – *knowledge acquisition* and *participation* – introduced by Sfard (1998), and emphasizes the role of collaboratively developed knowledge artifacts (ideas, solutions, models, products) as mediating elements and driving forces for learning and development.

The knowledge creation metaphor presents educators with new challenges since the goals and practices emphasizing creative work around knowledge objects assume changes in the conventional ways of designing educational settings in a detailed and carefully pre-structured manner (Lowyck & Pöysä, 2001; Palincsar & Herrenkohl, 2002). The processes and outcomes emerging in collaborative knowledge creation are shaped by somewhat unpredictable joint activity and interaction between the participants and, therefore, cannot be fully designed or structured in advance (Dillenbourg, 2002). And yet, many practitioners and researchers have witnessed that free, unguided, or unstructured collaborative work does not necessarily result in productive activity or meaningful learning (Kreijns, Kischner, & Jochems, 2003; Winn, 2002). Therefore, new approaches for pedagogical design are required that provide midway solutions between too strictly structured and fully self-directed activities.

The purpose of the present article is to introduce a research-based conceptual framework for examining pedagogical design efforts, explicating some essential components in supporting *technology-enhanced collaborative knowledge creation*. A *pedagogical infrastructure framework* is developed especially for providing researchers and educators with a conceptual tool for structuring the creation, description, and analysis of pedagogical designs of complex collaboration settings. The framework is supposed to be generic enough to be applied to various kinds of educational settings representing collaborative knowledge creation practices.

First, some existing approaches concerning the pedagogical design of collaborative settings are discussed and questioned, after which the new framework is introduced with a description of the studies through which it was developed. The application of the framework is demonstrated by examining the pedagogical design of three higher education courses that all represent technology-enhanced collaborative knowledge creation practices. Finally, some concluding remarks of the utility of the framework are presented.

PREVIOUS APPROACHES TO THE OVERALL DESIGN OF TECHNOLOGY-ENHANCED COLLABORATIVE LEARNING

In this section, we first comment on the insufficiency of existing notions and approaches meant for designing pedagogical support for complex settings representing collaborative knowledge creation and usage of technology.

Instructional Design Models

The research related to the design of educational settings and learning materials has predominantly been based on the models of *instructional design*. The instructional design approach has it roots in cognitive psychology, which considers learning as an individual process of acquiring new knowledge. The models mainly concentrate on the learning outcomes of individual students; they are commonly based on detailed pre-structuring of content and strict sequencing of activities, and they aim at creating a learning environment that supports the acquisition of a specific content or skill (Häkkinen, 2002; Jonassen & Land, 2000). Classic models of instructional design overlook the socio-cultural perspectives of orchestrating socially mediated activities; therefore, they are not very applicable for designing educational practices relying on collaboration and creation of new knowledge together (Gagne & Merrill, 1990).

In recent studies, the instructional design models are revised to be more suitable for designing complex, authentic tasks which are believed to result in qualitatively better learning outcomes. For instance, Merriënboer, Kirschner, and Kester (2003) suggested such design strategies as supporting 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 concentrate on designing educational settings mainly from the individual students' viewpoint, in situations where the learning of certain pre-defined content is the primary aim and through somewhat mechanical structuring of the process progression.

Scripting

One approach especially developed for designing the pedagogical support for technology-enhanced collaborative learning is using structured *scripts*, typically embedded in a technological learning environment. Scripts are a detailed set of guidelines, rules, and functionalities that support collaborative learning by constraining the co-learners' activities and thereby supporting coordination between distributed actors as well as guiding them through the collaborative learning process (Dillenbourg, 2002). Based on an analysis of existing scripts, Kollar, Fischer and Hesse (2006) concluded that scripts usually represent two kinds of support: a) those that provide support on a content-related or conceptual level and b) those that provide support related to the interactive processes between the collaborators. For example, Weinberger, Ertl, Fischer and Mandl (2005) designed *epistemic scripts* to facilitate students' knowledge creation activities and *social scripts* to structure the interaction of learners in a collaborative learning setting.

The design approach of scripting acknowledges the social dimension of learning but it is still mainly focused on supporting and stimulating individual learners' content acquisition via structuring of collaboration. Scripts are often designed for a special context and purpose, such as creating trust between the collaborators, as in the study of Mäkitalo, Weinberger, Häkkinen, Järvelä, and Fischer (2005). As Dillenbourg (2002) stated, scripts may disturb natural interaction and problem solving processes and may lead to the introduction of fake collaboration and arbitrary and superficial activity. In a later article, Dillenbourg and Tchounikine (2007) made a distinction between *micro-scripts* that support the interaction process in itself at a detailed level, and *macro-scripts* that set up higher-level conditions in which collaborative activity should occur. We maintain that **scripts** are not the all-round solution for designing an entire educational setting, but that they may provide an additional means for supporting learners in some specific epistemic or social aspects of the eligible activity. However, the support should be appropriately integrated with the overall design of an educational setting.

Distributed Scaffolding

A noteworthy perspective for 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 complex classroom settings should be distributed, in an integrated manner, across various tools and agents constituting students' learning environment, such as material resources, task structures, social arrangements, and technological tools, as well as teacher guidance. Examples of the elements that could be designed to actualize such distributed scaffolding are certain kinds of task sequencing, timely teacher interventions, and templates and prompts embedded in tools.

The notion of distributed scaffolding calls pedagogical designers to develop learning settings that integrate various means to support participants' learning activities. For instance, Hannafin, Hill, and McCarthy (2002) distinguished four types of potentially useful scaffolds embedded in tools to support knowledge creation activities: *conceptual* scaffolds assist the user in recognizing relationships and deciding what to consider; *metacognitive* scaffolds help learners to reflect on the goal or problem, relating prior knowledge and decision making in complex, ill-defined problems; *procedural* scaffolds assist learners with navigating in the implemented learning environments; and *strategic* scaffolds offer support to approach a task and reflect on existing expertise in the target domain.

Distributed scaffolding appears a promising idea for examining pedagogical support, but perhaps the concept of *scaffolding* is too narrow to describe the whole design challenge that educators face when designing educational units for collaborative knowledge creation. As Pea (2004) argued, the special meaning of the scaffolding concept should be maintained. Originally, the metaphor of scaffolding was used to describe adapted guidance provided by a more competent adult to help an individual learner in a problem-solving task that was otherwise beyond his or her skill (Wood, Bruner, & Ross, 1976). Further, the support was meant to be given only for as long as needed, until independent performance was achieved. The pedagogical design of an entire educational unit includes a wider scope than only the design of temporary support that the learners need for specific tasks and situations. For instance, the web-based environment that is used in some educational settings does not only scaffold participants' cognitive or collaborative learning efforts temporarily but also provides central cultural tools that are essential mediating elements throughout the collaborative knowledge creation process. Hence, the role of tools is broader than only a way for providing scaffolding, and this overarching role and relevance of tools in the enacted activities should be taken into account in the set-up of the whole educational unit.

Design Principles

One recent solution for designing complex learning settings is to define generic *design principles* that explicate central features of some pedagogical approaches to guide the designer (Kali, 2006). Design principles aim at guiding the construction of an educational setting with guidelines based on a specific learning theory; in this sense they can be regarded as normative, defining conditions for "ideal learning". A noteworthy example of applying this approach is the specification of knowledge building principles by Scardamalia (2002). Lee, Chan, and van Aalst (2006) investigated how students themselves may benefit from the usage of knowledge-building principles as criteria for a collaborative portfolio; their results witnessed that explicitly stated principles as guidelines fostered the deepening of inquiry and collaborative knowledge advancement.

In the context of an international KP-Lab project (Knowledge Practices Laboratory: www.kp-lab.org), a set of design principles were developed for a "trialogical" approach to learning, aiming at fostering knowledge creation practices that center around co-construction of knowledge objects through technological tools (Paavola & Hakkarainen, in press). The trialogical design principles have so far been applied for transforming the designs of current higher-education courses towards improved support for expert-like knowledge creation practices (Ilomäki & Paavola, 2008).

According to Bell, Hoadley, and Linn (2004), design principles are mediating generalizations between research findings and unique examples that emerge in practice, and they are meant for informing innovative educational practice rather than for falsifying scientific laws. They provide a good means to explicate which type of learning or knowledge practices a certain pedagogical approach is aiming at. This uniqueness of each set of design principles can also be regarded as a limitation of this approach, if the aim is to define generic, descriptive frameworks to be used widely in the examination of various kinds of educational settings, based on different pedagogical goals or assumptions.

CONSIDERING PEDAGOGICAL DESIGN AS THE BUILDING OF APPROPRIATE INFRASTRUCTURES

It appears that another kind of solution than scripting, distributed scaffolding or design principles is required to structure the examination of technology-enhanced collaborative knowledge creation pedagogues. Gavriel Salomon, an acknowledged pioneer in research on technology in education, had already written in 1992:

what matters is not just the design of a computer tool or program, not even the design of a single task or curricular unit. Rather, the cultivation of minds, which itself requires mindful engagement in a social process of meaning appropriation, requires that the whole learning environment, not just the computer program or tool, be designed as a well orchestrated whole. This includes curriculum, teachers' behaviors, collaborative tasks, mode of peer collaboration and interaction, tasks, learning goals, and the like. (p. 64, emphasis from the original reference).

Jones, Dirckinck-Holmfeld and Lindström (2006) stated that the set-up of computer-supported collaborative learning settings is based on *indirect design*, where the pedagogical conditions provide basic supporting structures that foster collaborative activity, but do not prescribe the exact activities or outcomes.

We suggest using the notion of *infrastructure* as a metaphor to illustrate how the pedagogical design of any collaborative learning setting resembles the construction of physical infrastructure, providing underlying support for desired activities (see also Guribye, 2005; Lipponen & Lallimo, 2004). We adopted the original idea from Bielaczyc (2006) who introduced the *social infrastructure* concept, stating that characteristic of successful computer-supported collaborative learning experiments is the building of an appropriate social infrastructure around technical infrastructure, such as classroom culture and norms established, classroom practices and online activities in the process, and the use of technology for collaboration and communication. Usually, infrastructure refers to technical or physical elements embedded in the system that are deliberately built into a society to provide for adequate functioning of people in their ordinary lives (Star, 1999). It appears a suitable notion also for describing the set of basic conditions that should be designed to shape and support collaborative activities in educational settings. According to Star, infrastructure is learned as part of membership and thus mediates cultural conventions for novices. Similarly, in a complex learning setting, the elements that build affordances for students' actions, designed by the teacher or based on the conventions of the educational institution, can be said to consist of components that form a *pedagogical infrastructure* that mediates cultural practices and directs students' learning activity both explicitly and implicitly (Lakkala, Muukkonen, Paavola & Hakkarainen, 2008).

The Pedagogical Infrastructure Framework

Based on several studies (see the next section), we have identified that educational settings that especially aim at fostering technology-enhanced collaborative knowledge creation should consist of deliberately designed *technical*, *social*, *epistemic*, and *cognitive* support structures. These critical components constitute the *pedagogical infrastructure framework*, meant to be used for constructing, examining, and evaluating the set-up of educational settings. One may argue that various other aspects should also be taken into account in pedagogical design, for instance motivational elements. However, we maintain that the chosen components highlight aspects that are essential, particularly for promoting collaborative knowledge creation practices, and that are not necessarily systematically considered in conventional pedagogical practices.

The framework itself is not normative; it does not prescribe how the technical, social, epistemological, or cognitive components of an educational setting should be designed (Lakkala, Muukkonen et al., 2008). The individual design solutions that would build up an appropriate and effective pedagogical infrastructure in each case depend on the goals and the intended nature of activity that the specific educational setting is supposed to promote; the framework just helps in examining, in a structured fashion, the basic features that are considered applicable for various types of cases. In Table 1, each component of the pedagogical infrastructure framework is briefly explained, together with the specification of design principles or criteria that would especially account for expert-like knowledge work and knowledge creation practices.

Table 1. The pedagogical infrastructure framework and recommended features of each component for educational settings aiming at collaborative knowledge creation.

Component	*Definition*	*Features promoting knowledge creation practices*
Technical	The providing of technology and technical advice to the participants; organizing and orchestrating the use of technology; the functionality of the tools provided; and their appropriateness for the desired activity	a) Providing of technology that enables and facilitates co-construction and elaboration of shared knowledge artifacts and coordination of the collaborative process; b) Easy access to technology in all phases of the process; c) Face-to-face and technology-mediated activities are highly integrated; d) Availability of guidance for using technology for expert-like knowledge practices.
Social	The combination of designed individual or collaborative student activities and required outcomes and actual arrangements to organize students' collaboration and social interaction	a) The whole process is openly shared between the participants; b) Students' assignments aim at truly collaborative co-construction of knowledge objects; c) Shared activities and responsibilities are explicitly regulated and defined; d) A supportive and constructive communication atmosphere is deliberately promoted; e) Students may have direct collaboration with professionals in the target field.
Epistemo-logical	The ways of operating with knowledge and the nature of knowledge processing that the assignments promote; nature of knowledge resources used; and the role	a) Students are engaged in solving complex, ill-defined problems through practices that explicitly and purposefully aim at creating new knowledge; b) Students use various knowledge sources; c) Knowledge is produced also for subsequent use; d) Students may be engaged in the real practices of a

	of participants and information resources while working with knowledge.	target field.
Cognitive	Designed tasks and artifacts or tools performing a modeling and reflective function for promoting students' self-regulative competencies to work in an intended way	a) Explicit modeling of expert-like knowledge practices through concrete models and templates; b) Methods used to promote self-reflection; c) Guidance provided for students about effective working strategies; d) Explicit scaffolding for collaborative knowledge creation processes embedded in tools.

We maintain that the pedagogical infrastructure framework can be used to classify, design, analyze, and compare the elements of various educational settings. The separate components exist in parallel and intertwined with each other, and in a successful educational setting, aiming at collaborative knowledge creation, all aspects are taken care of in an integrated way: technology works and is used appropriately, deliberate collaboration is built in the tasks and activities, the object of students' activity is genuine construction and elaboration of knowledge (not just individual internalization of certain content), and students' autonomy and the development of metaskills are supported by explicit cognitive modeling and reflection of expert-like practices.

Research Resulting in the Pedagogical Infrastructure Framework

As mentioned earlier, the first inspiration for developing the infrastructure approach for pedagogical design came from Bielaczyc (2006) who introduced the **social infrastructure** concept as complementary to *technological infrastructure* for collaborative learning. For instance, a study investigating the effects of technology mediation on students' engagement in collaborative inquiry (Muukkonen, Lakkala, & Hakkarainen, 2005) indicated that the scaffolding provided by the web-based collaboration software together with the possibility for dialogue through technology, supported practices of problem-setting, self-reflection, and collaborative development of ideas. In a subsequent study by Lakkala, Ilomäki and Palonen (2007), the implementation of distance learning through collaborative inquiry practices in a lower secondary school was investigated. The results indicated that the social arrangements (distance working and virtual collaboration in teams) as such were not the problem in the setting. The most difficult challenge for the students – and also for the teachers – appears to have been to understand the epistemic nature of the inquiry process and find effective ways to actualize it in practice. Also the web-based system used in the case did not have sophisticated tools for sharing or co-authoring of knowledge products, and this imperfect technical infrastructure appears to have discouraged sharing the entire, epistemic process-progression among the participants. The results highlighted the requirement for the teachers to explicitly influence students' attitudes towards knowledge work and practices of inquiry through systematic pedagogical support for epistemic actions. As Paavola, Lipponen, & Hakkarainen (2002) stated, innovative knowledge creation practices are fostered by an appropriate ***epistemological infrastructure***, referring to individual and collective practices of working with knowledge, treating knowledge as something that can be shared and developed, and deliberate efforts to engage in knowledge-creating inquiry.

In another study (Lakkala, Lallimo, & Hakkarainen, 2005), eight computer-supported collaborative inquiry projects in elementary and lower and upper secondary schools were compared using the technical, social, and epistemological infrastructures as categories for analyzing the designs. Social infrastructure was defined to include the social nature of activities (individual or collaborative activities and individual or collaborative products) and the structuring of collaboration (open collaboration or scaffolded collaboration). Epistemological infrastructure was specified to consist of the epistemic nature of activities (task-accomplishment, the sharing of ideas, or purposeful inquiry) and the structuring of activity (rigidly structured activity, open inquiry, or scaffolded inquiry). The results indicated that collaboration and inquiry strategies were not sufficiently guided and modeled for students, which was a clear weakness in the actualized designs, also reported by the participating teachers themselves. To conclude, explicit structuring and modeling of effective knowledge creation strategies appears to be a separate design task that requires special attention from the teacher. These results led to the first ideas of deliberately designed *cognitive infrastructure* needed for supporting students' intentional knowledge creation. If one wants students to improve their competencies in collaborative knowledge creation, educational settings should include elements that explicitly advance students' self-regulative competencies and metaskills for monitoring and regulating individual, collaborative, and knowledge-related aspects of the process (Bolhuis & Voeten, 2001; Muukkonen & Lakkala, 2009). Appropriate support could be provided by concrete *conceptual tools*, such as guidelines, models, templates, and scaffolds for planning, monitoring, and reflecting the work, or by *metacognitive tasks*, such as explicit justification of actions or reflection on the produced knowledge and processes (Choi, Land, & Turgeon, 2005; White & Fredriksen, 2005).

In the study by Lakkala, Muukkonen et al. (2008), the complete pedagogical infrastructure framework was specified and applied in the retrospective analysis of a design-based research effort consisting of four consecutive university courses applying collaborative inquiry. The framework helped to account for the characteristics of the design in each course through unifying terms and to compare the design features with the outcomes of the students' inquiry activity and self-reported experiences. Perhaps the most noteworthy benefit of the framework was that it provided a means to present an overview of various design features in a concise form, thereby facilitating the examination of the interplay between the components in each setting.

In a recent study, Muukkonen, Lakkala, and Paavola (in press) used the pedagogical infrastructure framework to compare the knowledge creation practices in two higher education courses. One was an applied cognitive psychology course in which the collaborative inquiry approach was implemented to replace conventional lecturing. The other was a course about organizational psychology in which students produced solutions for the knowledge problems of real clients, working according to a virtual teamwork model. The analysis of these two quite different settings through the framework revealed some consistent challenges that open-ended collaborative problem-solving assignments presented for students.

In summary, the pedagogical infrastructure framework has proven to be applicable for analyzing specified pedagogical designs in greater depth, but also more generally and from different perspectives, comparing separate designs.

EVALUATING THREE COURSE DESIGNS THROUGH THE PEDAGOGICAL INFRASTRUCTURE FRAMEWORK

In this section, three higher education courses from different subject domains are described through the pedagogical infrastructure framework to illustrate its usage for examining educational settings aiming at promoting collaborative knowledge creation mediated by technology. For each case, first the specific pedagogical approach and goal of the course is described, and then the elements of the course design, using the technical, social, epistemological, and cognitive components, are defined through the features that are considered essential for knowledge creation pedagogy (see Table 1). In addition, suggestions are made to improve the pedagogical design of each course, in order to better foster collaborative knowledge creation practices. The descriptions are based on explorative and interpretative analysis of multiple data collected from the courses for research purposes (observations, teacher interviews, database content, etc.).

Some results of the courses are reported by Kosonen, Ilomäki, and Lakkala (2008) concerning Case 2 and by Lakkala, Kosonen, Bauters, and Rämö (2008) concerning Case 3.

Case 1: Question-Driven Knowledge Creation Through Wiki

The case includes a course titled "Emerging research themes in Psychology", conducted in the Autumn of 2008 and targeted at undergraduate and post-graduate students of the Faculty of Behavioral Sciences in the University of Helsinki, Finland. The language of the course was English and therefore about half of the participants were international exchange students. The course lasted one study period of seven weeks with two hour weekly lecture meetings followed by one hour voluntary hands-on practicing in a computer lab. In addition, students had two weeks' time to submit their final reports after the last meeting.

Objectives: The objective of the course was to introduce emerging research themes in psychology that are not taught in regular courses of the department and, hence, offer fresh perspectives on psychology as a science.

Pedagogical approach and course activities: Students were introduced to research themes (e.g., transactive memory, knowledge creation approach to learning, user experience in digital gaming) in seven lectures held by expert researchers presenting their own investigations. The course was based on expert lecturing, but conventional lecture course practices were transformed and enriched by collaborative virtual inquiry assignments between the weekly lectures. Students were engaged in critical reflection on the introduced research themes and methodologies through joint questioning and co-construction of written explanations through a wiki application. Each theme was first discussed vividly during the course meetings. After each lecture, participants posted questions regarding the lecture in a shared wiki area, and the teacher categorized and structured the questions for joint writing. There was the possibility for hands-on work in a computer lab with the help of the teachers after each lecture. Before the next lecture, participants wrote their own viewpoints concerning the created questions, building on each others' writings on the wiki. To enhance productive collaboration, students were first directed to introduce themselves on the wiki through an introductory text. As a final task, students produced a written final report from a chosen question or theme individually or in pairs, and submitted the reports to the shared wiki.

Technology used: A version of Confluence wiki, available for all university students, was used as a shared virtual space for the course. The teachers carried out the basic structuring of the pages.

Table 2. Analysis of the pedagogical infrastructure in Case 1.

Component	*Essential design features of the setting*	*Shortcomings in the design and suggestions for improvements*
Technical	a) Wiki application as a tool instead of more familiar discussion forum to engage students in co-construction activities that go beyond discussion-type communication; wiki offered proper tools for co-editing of textual objects; b) Easy access to wiki through Internet; c) Wiki activity was an integrated continuation of discussions in lectures; d) A possibility for hands-on practicing with tutor offered after each lecture.	Wiki was inflexible for linking and rearranging created content items. A better tool for explicating mutual relationships and enabling rearrangement of created questions, concepts, and explanations would support more advanced knowledge construction.

Social	a) Shared question and explanation formulation; b) An assignment for building on others' viewpoints in wiki; c) Freedom to produce final reports individually or in pairs; d) Acquainting students with each other through an explicit task to introduce oneself; promotion of spontaneous face-to-face discussion during the lectures; e) Lecturers were professional researchers presenting their authentic studies.	Not enough time for discussions during the lectures; participants reported it to be challenging to start formulating questions on a new theme alone. Each lecture should be shorter, reserving more time for collaborative reflection. Apart from one pair, all students produced their final reports alone. Pair or group work should be compulsory if the goal is to engage students in collaborative knowledge construction.
Epistemo-logical	a) Question-driven inquiry through wiki promoted questioning and critical examination of the themes; no fixed content to be mastered as such; b) Various scientific resources were shared with students; students were also expected to search for additional references themselves; b) Wiki texts used for writing the final reports but no systematic plans for exploiting the material after the course; d) Atypical course content: lectures resembled scientific conference presentations more than teaching lectures; contents was challenging for those not familiar with the topics beforehand.	Joint question-formulation and elaboration of viewpoints succeeded well within each theme but more overarching (methodological or theoretical) questioning and reflection across the themes remained modest. Individual final reports were high level in terms of examining some themes deeper but their mutual integration was not achieved.
Cognitive	a) Written guidelines for course practices and basic template for final reports provided; b) Students were engaged in a reflection activity after the course through writing about issues that were significant, important, interesting, or central for them in the course experience. c) The teachers, as experts in the field, supported question-driven knowledge creation by categorizing students' questions, structuring the theme areas and contributing to the joint writing; teachers gave written feedback on the final reports through the wiki; d) No built-in scaffolding in the tools.	The question-formulation and co-writing activities through the wiki were experienced challenging because the way of working was new for the students; more time should be reserved practicing the working strategies during meetings, for instance in small groups guided by the teachers. Reflection on practices and outcomes remained an individual venture (even though shared through the wiki) and some students did not do it at all; reflection should be organized as a compulsory, joint activity.

Case 2: Qualitative Methods Seminar

The course was a seminar about qualitative research methods, conducted in the Autumn of 2006 at the Department of Behavioral Sciences in the University of Helsinki, Finland. It was targeted at students preparing their master thesis (or starting their doctoral studies) but who did not have much formal education about qualitative methods. The course lasted one study period of seven weeks with two hour weekly meetings and virtual work between the meetings.

Objectives: The aim was to support students' research practices, especially using qualitative methodology, in the concrete context that the students' own master theses provided. Typically research methods in higher education include lecturing complemented by small-scale practical exercises; such general method courses do not usually match with students' needs in their own research processes.

Pedagogical approach and course activities: The activities during the seminar simulated the knowledge practices of a real research community; the participants were at the same time in the role of a student learning research methods and novice researchers conducting their own studies. The pedagogical model consisted of interrelated elements, jointly contributing to the building of a comprehensive knowledge base and competencies for justifying and applying methodological choices in research practice: 1) conceptualization of domain concepts through constructing and revising concept maps in pairs; 2) conducting authentic research by applying the methods in real, personal research cases regarding students' own theses; 3) participating in a research community by arguing and defending methodological solutions, guided by more experienced researchers, and using authentic research examples, journals, and handbooks as information sources. Students explored qualitative methods and defined a specific methodological question, essential and important for their own study at that time. The content of the seminar meetings was constructed around students' presentations of their own questions. During the meetings, students worked in pairs; each pair shared the same methodological interest. Concept maps related to their interests were revised in each meeting according to new viewpoints that students got from other presentations. During the periods between the meetings, the students prepared their presentations in pairs, shared materials related to the presentations in the web-based environments, and conducted some discussions there concerning qualitative methods. Each student also continued working on their own thesis individually.

Technology used: Specific software, CmapTools (http://cmap.ihmc.us/conceptmap.html), was used for enabling and facilitating the creation and iterative modification of the concept maps in pairs. A web-based collaboration environment, FLE3 (fle3.uiah.fi), was used for sharing the process (background materials, presentation documents, discussions, and commenting) between course participants both during and between the seminar meetings. In addition, ordinary office applications, such as e-mails, word processing, and presentation tools, were used by the students.

Table 3. Analysis of the pedagogical infrastructure in Case 2.

Component	*Essential design features of the setting*	*Shortcomings in the design and suggestions for improvements*
Technical	a) CMapTools was designed for creating and revising concept maps. FLE3 enabled saving and sharing presentations and concept maps, and scientific resources provided by the teacher; it also enabled communication between the meetings; b) Seminar meetings held in a computer lab with portable computers and access to basic	The implementation of two different technical systems and a separate university file management system used through portable computers created technical problems for the students; it was not possible to easily integrate

	office applications, internet connections and scientific databases. CMapTools and FLE3 available through internet; file management system accessible only in university premises; c) Same tools and systems used both during and between meetings; d) The teacher and a tutor guided students in seminar meetings.	materials in separate systems. Applications that would enable all activities to be conducted in one place or highly integrated tools that are easy to use would better support the course activities.
Social	a) Course participants worked as a community in face-to-face and virtual discussions, sharing ideas and solutions; b) Students coming to the course had individual research problems based on their own theses; pairs (or individuals) prepared methodological presentations; c) pairs were formed of students with the same methodological interests; concept maps about qualitative methods were also created and revised in pairs. d) A supportive and constructive communication atmosphere was deliberately promoted by the teacher; e) The teacher of the course was a professional researcher giving examples from her own studies.	Students contributed to other participants' research efforts by discussing and reflecting on them in meetings and experienced a supportive atmosphere. More considered commenting and reflection efforts on others' work could, however, be added in the activities, e.g., by explicit tasks to comment on others' presentations and concept maps virtually between the meetings.
Epistemo-logical	a) The content of the course was based on the questions introduced by the participants; b) Scientific resources (articles, handbooks) were provided by the teacher and sought by the students themselves; c) Activities integrated tightly with the students' own research; the participants were also intended to apply and elaborate on the knowledge and skills in their personal theses after the course; d) Students' presentations about methodological issues resembled those in scientific conferences and workshops, and the teacher's presentations and case examples shared and demonstrated expert practices.	A visit of an external professional researcher discussing qualitative methods from the perspective of his or her expertise was conceived in the course scenario. The visit did not actualize because of practical obstacles. Such a visit would have complemented the role of the teacher as a professional researcher, showing cross-fertilization between study practices and professional research practices.
Cognitive	a) Students received templates and guidelines of scientific standards concerning the construction of a methods section in a scientific article; b) Reflection on one's own understanding of qualitative research methods by preparing and	Usually students produced from two to five versions of the concept maps to reflect their models of qualitative methods. However, some students produced only one

	iteratively developing conceptual models (concept maps) and reflection on methodological solutions through discussions based on the research cases of the participants were expected; c) Teacher as an expert researcher demonstrating professional problem-solving through commenting on the participants' research cases; d) No built-in scaffolding in the tools.	map; more deliberate attention should be paid to direct and motivate all students to put efforts into this conceptualization and reflection activity.

Case 3: Collaborative Design Course for Engineering Students

The case was a compulsory term project in the domain of media engineering, conducted in the Spring of 2007 and targeted at third year media technology students in EVTEK (later Metropolia) University of Applied Sciences, Espoo, Finland. The course lasted about four months, including four joint meetings and several team meetings among the students and with the customers.

Objectives: The goal of the course was to learn collaborative design practices and project-based working methods for solving the practical problems of media technology. An engineering education should prepare students for professional design and software development practices of the present day and for their future working lives. One sophisticated solution is to create possibilities for true cross-fertilization of expertise between students and professionals in workplaces.

Pedagogical approach and course activities: Through a so-called term project, students gradually improved their knowledge practices in managing projects and dealing with real situations. Students were meant to conduct a realistic design task for a real client (e.g. a multimedia product or a website application), using professional design project models, methods, and multimedia tools. Students communicated directly with the representatives of the client organization and developed their drafts and final products through close collaboration and joint meetings with them. The final products were actually used in the client organizations after the course; therefore, students had to take into account the real needs of the clients' domains. The students had the freedom to conduct the project alone or in teams and to choose the customer and project objective from those that the teacher offered or to source them themselves. Some students were paid for their project work by the customer. In one lecture, a former student presented "lessons learnt" viewpoints and guidelines for avoiding the pitfalls of project work. At the end of the course, each team presented their project to the other course participants. The main part of the course consisted of project work periods, during which the teams worked independently among themselves and with the client, as well as posting the specified project documents, such as a project plan, a prototype, or a final report, onto the shared virtual system. Each student and each team was given the assignment of writing a self-evaluation at the end of the course.

Technology used: An intranet system, OVI-portal, generally used in all courses in EVTEK, was used as a forum for arranging the students' course participation, announcements, materials, and task assignments. All lectures and presentations conducted during the course were videotaped and made available for the participants through the web afterwards. The teacher organized the delivery, sharing, and monitoring of the project teams' documentation through a special, web-based project tool, NetPro, developed in EVTEK. In addition, the students were provided with various professional multimedia tools for creating the multimedia products designed in their teams.

Table 4. Analysis of the pedagogical infrastructure in Case 3.

Component	*Essential design features of the setting*	*Shortcomings in the design and suggestions for improvements*
Technical	a) OVI-portal was used for administrative course management issues; NetPro system served for uploading and sharing finalized project documentation materials and for the teacher to keep track of the project progression; b) OVI-portal and NetPro were available through the internet; on university premises, the students had access to professional multimedia applications for producing the multimedia products; c) Design work in teams was conducted mainly through face-to-face meetings and email; web technology was used for sharing finalized documents; d) Technical support was available in the university for professional tools if needed.	Tools were not used for elaboration, commenting, or editing of the design objects or coordinating the collaborative process; mainly e-mail was used for internal communication. More sophisticated tools for co-construction of knowledge objects (e.g. wiki, file versioning) should be provided. Sharing of the design process virtually with the client was not possible due to the lack of extranet services. Special attention should be paid to providing technological systems that would enable virtual collaboration with external customers.
Social	a) Outcomes from separate projects shared through finalized documents and oral presentations; b) The assignment of designing a multimedia product for a customer created a strong shared object in project teams; c) The responsibilities inside the teams were divided between the members by assigned roles (e.g. project manager); course grading was based on both team outcomes and personal learning logs; d) Course activities were mainly based on team work; each team was responsible for creating their own working atmosphere; e) Project teams took care of direct collaboration with the client; the teams were supposed to meet the clients on a regular basis.	The project model taught to the engineering students appeared to follow the conventions of dividing the labor and responsibilities between the team members. The models should explicitly enforce collaborative development of design documents, e.g. by defining explicit milestones for reviewing and contributing to shared documents. Students had the freedom to conduct the project alone and collaborate only with their individually arranged client; not all project teams maintained regular contacts with their clients. If the goal is to practice collaborative design, team work and contacts with clients should be compulsory.
Epistemo-logical	a) The authentic design task required students to apply prior domain knowledge and new knowledge in a versatile way;	A four month-long course period turned out to be a short time for such a complex, iterative

	b) The process involved such knowledge activities as surveys on existing solutions for similar design problems, creation of prototypes, and evaluations of these intermediary products with the client; b) Final products were created for real use by the client; d) The students were supposed to find out their clients' needs and expectations and convert this knowledge into user requirements directing the design process.	assignment; the teacher had to be flexible with the deadlines for delivering the project outcomes; this problem relates also to institutional-level decisions for organizing study programs.
Cognitive	a) Professional project work models and document templates provided guidelines for explicating design solutions and organizing the process; an alumni student lectured about lessons learnt in project work; b) There was an intermediate review of each team with the teacher and a final plenary review session of all projects; students were directed to reflect on the design process both individually and in teams; c) The teacher actively participated in the meetings with clients in some projects, acting as an expert and providing situation-specific guidance for the students; d) File sharing space of the NetPro system was structured according to the professional project documentation model.	The project teams mainly created the documentation afterwards, simultaneously with the delivery of the final product; the students did not appear to realize the role of explicit planning and reflection of design work throughout the process. More systematic planning and monitoring practices and delivery of documents on time should be required by the teacher. The guidance for the project teams was somewhat arbitrary – the teacher followed and supervised some teams closely but left other teams and their outcomes unattended.

CONCLUDING REMARKS

In our previous studies, the pedagogical infrastructure framework was mainly applied to analyze fairly identical pedagogical practices following the collaborative inquiry approach. In the present article, the educational settings used as examples represented more varying pedagogical approaches, albeit all following the practices of collaborative knowledge creation. The use of the framework in the cases was descriptive, based on interpretative analysis of the specific, unique features in each setting. Although the introduced framework is abstract and generic, we maintain that it provided a novel perspective for examining the course designs, and offered conceptual means to focus on some fundamental aspects in the designs, especially related to promoting collaborative knowledge creation practices.

An applicable methodology for examining the design of complex learning settings appears to be the combination of a descriptive framework and prescriptive design principles: the generic pedagogical infrastructure framework explicates what elements to concentrate on or to incorporate into the analysis, and the design principles or criteria define what characteristics those elements should have or include in order to reach the goals of the chosen pedagogical approach. Such a strategy enabled the explication of some shortcomings and suggestions for improvements in the presented cases concerning knowledge practices, such as suggestions to provide participants with technological tools with more flexible and appropriate affordances for co-construction of knowledge objects than the existing tools, or to require more explicit and deliberate collaborative activity in shared tasks and outcomes.

In the scope of the present article, we found that it was somewhat difficult to rise above individual cases and to compare the settings with each other, or to more systematically explicate some overarching features in a similar way for all cases. The pedagogical infrastructure framework was primarily introduced as a tool for analyzing and evaluating existing designs, but it may also support educational practitioners when they implement a collaborative knowledge creation approach in their educational practices. For that purpose, a more detailed and specific framework including explicit guidelines or categories and examples would be needed. An interesting and fruitful endeavor could be a research and design project, conducted together with some knowledgeable educators, testing whether the framework helps them to evaluate their course designs in more systematic way, and working with the educators to develop and concretize the framework further.

REFERENCES

Bell, P., Hoadley, C. M., & Linn, M. C. (2004). Design-based research in education. In M. C. Linn, E. A. Davis, & P. Bell (Eds.), *Internet environments for science education* (pp. 73-85). Mahwah, NJ: Erlbaum.

Bereiter, C. (2002). *Education and mind in the knowledge age*. Hillsdale, NY: Erlbaum.

Bielaczyc, K. (2006). Designing social infrastructure: Critical issues in creating learning environments with technology. *Journal of the Learning Sciences, 15*(3), 301-329.

Bolhuis, S., & Voeten, M. J. M. (2001). Toward self-directed learning in secondary schools: What do teachers do? *Teaching and Teacher Education, 17*, 837-855.

Choi, I., Land, S. M., & Turgeon, A. J. (2005). Scaffolding peer-questioning strategies to facilitate metacognition during online small group discussion. *Instructional Science, 33*(5-6), 483-511.

Dillenbourg, P. (2002). Over-scripting CSCL: The risk of blending collaborative learning with instructional design. In P. A. Kirschner (Ed.), *Three worlds of CSCL: Can we support CSCL?* (pp. 61-91). Heerlen: Open Universiteit Nederland.

Dillenbourg, P., & Tchounikine, P. (2007). Flexibility in macro-scripts for computer-supported collaborative learning. *Journal of Computer Assisted Learning, 23*(1), 1-13.

Gagne, R. M., & Merrill, M. D. (1990). Integrative goals for instructional design. *Educational Technology Research and Development, 38*(1), 23-30.

Guribye, F. (2005). *Infrastructures for learning: Ethnographic inquiries into the social and technical conditions of education and training*. Doctoral dissertation, University of Bergen, Bergen, Norway. Retrieved July 5, 2009, from: http://hdl.handle.net/1956/859.

Hannafin, M.J., Hill, J., & McCarthy, J. (2002). Designing resource-based learning and performance support systems. In D. Wiley (Ed.), *The instructional use of learning objects* (pp. 99-129). Bloomington, IN: Association for Educational Communications & Technology.

Häkkinen, P. (2002). Challenges for design of computer-based learning environments. *British Journal of Educational Technology, 33*(4), 461-469.

Ilomäki, L., Lakkala, M., & Paavola, S. (2006). Case studies of learning objects used in school settings. *Learning, Media, and Technology, 31*(3), 249-267.

Ilomäki, L & Paavola, S. (2008). Developing and applying design principles for knowledge creation practices. In G. Kanselaar, J. van Merriënboer, P. Kirschner, & T. de Jong (Eds.), *International Perspectives in the Learning Sciences: Cre8ing a Learning World, Proceedings of the Eighth International Conference for the Learning Sciences (ICLS 2008)*, Volume 3 (pp. 258-259). Utrecht, The Netherlands: International Society of the Learning Sciences (ISLS).

Jonassen, D. H., & Land, S. M. (2000). *Theoretical foundations of learning environments*. Mahwah, NJ: Erlbaum.

Jones C., Dirckinck-Holmfeld, L., & Lindström, B. (2006). A relational, indirect, meso-level approach to CSCL design in the next decade. *International Journal of Computer-Supported Collaborative Learning, 1*(1), 35-56.

Kali, Y. (2006). Collaborative knowledge building using a design principles database. *International Journal of Computer-Supported Collaborative Learning, 1*(2), 187-201.

Kollar, I., Fischer, F., & Hesse, F. W. (2006). Collaboration scripts – A conceptual analysis. *Educational Psychology Review, 18*(2), 159-185.

Kosonen, K., Ilomäki, L., & Lakkala, M. (2008). Conceptual mapping as a form of trialogical learning intervention. In G. Kanselaar, J. van Merriënboer, P. Kirschner, & T. de Jong (Eds.), *International Perspectives in the Learning Sciences: Cre8ing a Learning World, Proceedings of the Eighth International Conference for the Learning Sciences (ICLS 2008)*, Volume 3 (pp. 260-262). Utrecht, The Netherlands: ICLS.

Kozma, R. B. (2003). Technology and classroom practices: An international study. *Journal of Research on Technology in Education, 36*, 1-14.

Kreijns, K., Kirschner, P. A., & Jochems, W. (2003). Identifying the pitfalls of social interaction in computer-supported collaborative learning environments: A review of the research. *Computers in Human Behavior, 19*(3), 335-353.

Lakkala, M., Ilomäki, L., & Palonen, T. (2007). Implementing virtual, collaborative inquiry practices in a middle school context. *Behaviour & Information Technology*, *26*(1), 37-53.

Lakkala, S., Kosonen, K., Bauters, M., & Rämö, E. (2008). Cross-fertilization of collaborative design practices between an educational institution and workplaces. Poster presented at the 4th EARLI SIG 14 Learning and Professional Development Conference. University of Jyväskylä, Jyväskylä, Finland. Retrieved July 5, 2009, from http://www.kp-lab.org/project-overview/dissemination-material/kp-lab-posters/Lakkala_EARLI-Sig-14_2008.pdf.

Lakkala, M., Lallimo, J., & Hakkarainen, K. (2005). Teachers' pedagogical designs for technology-supported collective inquiry: A national case study. *Computers & Education, 45*(3), 337-356.

Lakkala, M., Muukkonen, H., Paavola, S., & Hakkarainen, K. (2008). Designing pedagogical infrastructures in university courses for technology-enhanced collaborative inquiry. *Research and Practice in Technology Enhanced Learning, 3*(1), 33-64.

Lee, E. Y. C, Chan, C. K. K., & van Aalst, J. (2006). Students assessing their own collaborative knowledge building. *International Journal of Computer-Supported Collaborative Learning, 1*(2), 277-307.

Lipponen, L., & Lallimo, J. (2004). From collaborative technology to collaborative use of technology: Designing learning oriented infrastructures. *Educational Media International, 41*(2), 111-116.

Lowyck, J., & Pöysä, J. (2001). Design of collaborative learning environments. *Computers in Human Behavior, 17*(5-6), 507-516.

Merriënboer, J. J. G., Kirschner, P. A., & Kester, L. (2003). Taking the load off a learner's mind: Instructional design for complex learning. *Educational Psychologist, 38*(1), 5-13.

Muukkonen, H., & Lakkala, M. (2009). Exploring metaskills of knowledge-creating inquiry in higher education. *International Journal of Computer-Supported Collaborative Learning, 4*(2), 187-211.

Muukkonen, H., Lakkala, M., & Hakkarainen, K. (2005). Technology-mediation and tutoring: How do they shape progressive inquiry discourse? *The Journal of the Learning Sciences, 14*(4), 527-565.

Muukkonen, H., Lakkala, M., & Paavola, S. (in press). Promoting knowledge creation and object-oriented inquiry in university courses. In S. Ludvigsen, A. Lund, & R. Säljö, R. (Eds.), *Learning in social practices. ICT and new artifacts - transformation of social and cultural practices*.

Mäkitalo, K., Weinberger, A., Häkkinen, P., Järvelä, S., & Fischer, F. (2005). Epistemic Cooperation Scripts in Online Learning Environments: Fostering Learning by Reducing Uncertainty in Discourse? *Computers in Human Behavior, 21*(4), 603-622.

Paavola, S., & Hakkarainen, K. (2005). The knowledge creation metaphor – An emergent epistemological approach to learning. *Science & Education, 14*, 535-557.

Paavola, S., & Hakkarainen, K. (2009). From meaning making to joint construction of knowledge practices and artifacts – A trialogical approach to CSCL. In C. O'Malley, D. Suthers, P. Reimann, & A. Dimitracopoulou (Eds.), *Computer Supported Collaborative Learning Practices: CSCL2009 Conference Proceedings*. (pp. 83-92). Rhodes, Creek: International Society of the Learning Sciences (ISLS).

Paavola, S., Lipponen, L., & Hakkarainen, K. (2002). Epistemological foundations for CSCL: A comparison of three models of innovative knowledge communities. In Stahl, G. (Ed.), *Computer support for collaborative learning: Foundations for a CSCL community* (pp. 24-32). Hillsdale, NY: Erlbaum.

Palincsar, A. S., & Herrenkohl L. R. (2002) Designing collaborative learning contexts. *Theory into practice, 41*(1), 26-32.

Pea, R. (2004). The social and technological dimensions of scaffolding and related theoretical concepts for learning, education and human activity. *Journal of the Learning Sciences, 13*(3), 423-451.

Puntambekar, S., & Kolodner, J. L. (2005). Toward implementing distributed scaffolding: Helping students learn science from design. *Journal of Research in Science Teaching, 42*(2), 185-217.

Salomon, G. (1992). What does the design of effective CSCL require and how do we study its effects? *ACM SIGCUE Outlook, 21*(3), 62-68.

Scardamalia, M. (2002). Collective cognitive responsibility for the advancement of knowledge. In B. Smith (Ed.), *Liberal education in the knowledge society* (pp. 67-98). Chicago, IL: Open Court.

Sfard, A. (1998). On two metaphors for learning and the dangers of choosing just one. *Educational Researcher, 27*, 4-13.

Star, S. L. (1999). The ethnography of infrastructure. *American Behavioral Scientist, 43*(3), 377-391.

Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes*. Cambridge, MA: Harvard University Press.

Weinberger, A., Ertl, B., Fischer, F., & Mandl, H. (2005). Epistemic and social scripts in computer-supported collaborative learning. *Instructional Science, 33*(1), 1-30.

White, B., & Fredriksen, J. (2005). A theoretical framework and approach for fostering metacognitive development. *Educational Psychologist, 40*, 211-223.

Winn, W. (2002). Current trends in educational technology research: The study of learning environments. *Educational Psychology Review, 14*(3), 331-351.

Wood, D., Bruner, J. S., & Ross, G. (1976). The role of tutoring in problem solving. *Journal of Child Psychology and Psychiatry, 17*, 89-100.