Unfolding Experienced Teachers' Pedagogical Practices in Technology-enhanced Collaborative Learning

Minna Lakkala, Liisa Ilomäki, Institute of Behavioural Sciences, P.O. Box 9, 00014 University of Helsinki, Finland
Email: minna.lakkala@helsinki.fi, liisa.ilomaki@helsinki.fi

Abstract: Several studies address the problem that the pedagogically meaningful usage of technology does not propagate easily; new methods for teacher training are needed. One method is to distribute experienced teachers' cultivated practices as examples, but good ways of presenting the essential aspects of these exemplary practices should be developed. The study examined how two experienced primary teachers constructed technology-enhanced collaborative learning units in order to document these examples as training materials. The first case was an inquiry project in biology; the second case focused on the virtual publishing of a Web journal. The Pedagogical Infrastructure Framework, including technical, social, epistemological and cognitive components, was applied in the analysis. The results revealed that experienced teachers planned long-term, goal-oriented processes consisting of well-organized activities where various elements of the pedagogical infrastructure were coherently integrated, which provided pupils with the possibility to practice challenging technical and academic skills in a meaningful context. Based on the analysis, ideas for the further development of teacher training materials are discussed.

Introduction

Modern digital technologies are considered to provide new, valuable possibilities for education. Yet research results indicate that pedagogical change in schools through information and communication technology (ICT) has not actualized as expected. Technology is still infrequently used by few teachers and is often relegated to traditional teaching methods such as sharing information or doing simple, mechanical exercises instead of being used to advance collaborative work, creative activities and the solving of complex, authentic problems or to support students' knowledge management skills (OECD, 2010; Smeets, 2005). ICT is not used to transform pedagogical practices but to support the teaching of domain content, and the school use of ICT is boring and monotonous (Gibson & Oberg, 2004; Pedersen et al., 2006).

In teacher training programs, technology, pedagogy and subject domain content are often taught separately, which does not necessarily provide teachers with competencies for integrating them adequately into classroom practice (Hyo-Jeong & Kim, 2009). Teachers would benefit from concrete, practical examples of using technology in real classroom settings and the combining of technical and pedagogical training (Pedersen et al., 2006; Putnam & Borko, 2000). To develop exemplary material for in-service teacher training, we examined and documented how two experienced teachers applied digital technology in their real classroom practices. The main idea was to disseminate examples that represent challenging pedagogical approaches, including the rich use of technology and complex activities, and to draw on experienced teachers' well-tried and cultivated practices. Many studies have examined the innovative usage of ICT in teaching (e.g., Kozma & Anderson, 2002), but the studies have not focused on unfolding experienced teachers' established, refined classroom practices with ICT in detail, in order to create best practice models for other teachers.

The aim of the present study was to investigate how two experienced primary school teachers constructed a learning setting for their pupils through the overall design and timely scaffolding of classroom activities. The Pedagogical Infrastructure Framework, developed in our previous studies, was used as an analysis framework for unfolding and describing the pedagogical elements and solutions in the expert teachers' designs and practices. First, the Pedagogical Infrastructure Framework is shortly explained, after which the methods and results of the study are described. At the end of the article, some conclusions are made about the issues that appear exceptional and worth disseminating in experienced teachers' pedagogical practices with technology.

The Pedagogical Infrastructure Framework

To unfold the central elements in the teachers' pedagogical practices, especially in technology-enhanced collaborative knowledge creation activities, we illustrated the organization of an educational setting as building up an appropriate *pedagogical infrastructure*. The idea for using the notion of infrastructure as a metaphor was adopted from previous studies (Bielaczyc, 2006; Paavola, Lipponen & Hakkarainen, 2002), to emphasize how the pedagogical design of collaborative settings is indirect in that it sets up background conditions that mediate intended social and cultural practices but does not prescribe the contents or tasks in detail (Jones, Dirckinck-Holmfeld & Lindström, 2006).

The approach has been developed further in our own studies (e.g., Lakkala, Muukkonen, Paavola & Hakkarainen, 2008), resulting in the *Pedagogical Infrastructure Framework*. It specifies four essential support structures - *technical*, *social*, *epistemic* and *cognitive* – that are considered important to include in the design of learning settings. The components are chosen in order to highlight aspects that are essential particularly for promoting technology-enhanced collaborative knowledge creation practices, but which are not necessarily emphasized or systematically considered in conventional pedagogical practices. The framework, as such, is not normative; it merely helps to examine and evaluate the design features in a structured fashion, drawing the designers' or researchers' attention to some critical but often unnoticed elements in the setting (Lakkala, 2010). The basic components are defined in the following way:

1) *Technical conditions*: What kind of technology and tools are in use? The provision of technology and technical advice to the participants, the organization and orchestration of the use of technology, and the functionality of the tools provided and their appropriateness for the desired activity.
2) *Social conditions*: How is collaboration organized and supported? The combination of designed individual or collaborative student activities and required outcomes; the organization of students' collaboration and social interaction.
3) *Epistemological conditions*: Why, how and by whom is knowledge produced? The ways of operating with knowledge and knowledge practices that the assignments promote, the nature of the information resources used, and the role of the participants and information resources in working with knowledge.
4) *Cognitive conditions*: How can the intended activity and competence improvement be explicitly supported and scaffolded? Designed tasks and artifacts or tools that perform a modeling and reflective function for promoting students' self-regulative competencies to work in an intended way.

A teacher's role in setting up technology-enhanced collaborative learning settings can be divided into two main tasks (see also Hogan & Pressley, 1997): first, planning, organizing and structuring the overall activity by establishing the underlying pedagogical conditions for the collective effort (*overall design*), and secondly, participating in the activities as a guide and expert who provides adapted, situation-specific guidance to the learners when needed (*scaffolding*). In the present study, both the overall design and the scaffolding activities of the experienced teachers were examined through the components of the Pedagogical Infrastructure Framework.

Methods

The general methodological approach in the present study was a multiple case study approach (Yin, 2003) where two primary school teachers' educational units in their classrooms were investigated. For the data analysis, we used descriptive and qualitative content analysis methods to unfold the teachers' pedagogical practices based on multiple types of data.

Research Context

The educational cases investigated in the study represented the Finnish cases in an international FICTUP project (Fostering ICT Usage in Pedagogical practices; see http://www.fictup-project.eu) supported by the EU. The aim of the project was to create training materials (written pedagogical scenarios and related short videos) describing concrete pedagogical activities using ICT, to experiment with a close tutoring process among experienced and novice teachers, and to provide training institutions with recommendations based on the experimentations. The present study focuses on the pedagogical units carried out by two experienced teachers from Finnish elementary schools. The training materials created for the cases are available on the FICTUP project website (FICTUP pedagogical scenario, 2010a; FICTUP pedagogical scenario, 2010b).

Participating Teachers and Their Pedagogical Cases

Two primary school teachers participated in the study, conducting technology-enhanced collaborative learning units in their classrooms. The teachers were experienced in the pedagogical use of ICT, they had participated in various development projects, and they were acknowledged teacher trainers on the communal level. Their practices with ICT have also been evaluated as advanced in previous studies (see the case 'Rome' in Lakkala, Lallimo & Hakkarainen, 2005, and the case 'Do you eat healthily' in Ilomäki, Lakkala & Paavola, 2006), and they were chosen as tutors for the FICTUP project because of their expertise in the pedagogical use of ICT. The cases were designed and conducted by the teachers themselves, and they represented the teachers' ordinary practices, which were not earlier influenced by the Pedagogical Infrastructure Framework.

In *Case 1*, titled 'Exploring growth factors', primary school pupils from the 3rd grade (9-10 years of age) studied wild courtyard plants and practiced the construction of a simple experimental design related to growth factors. They carried out an inquiry project in small groups, practicing scientific skills such as formulating research questions and hypotheses, searching for information, making and documenting observations, and writing and commenting on scientific explanations. The duration of the unit was ten lessons over three weeks; successive lessons varied from one to three lessons during the same day. Online working

spaces of the Web-based collaboration system Fronter (http://com.fronter.info/) organized by the teacher were used to structure the inquiry process. The educational objectives of the unit related to learning the subject domain content (to understand the role of growth factors for wild courtyard plants) as well as to improving more general skills, such as writing, information search, categorization of knowledge, science skills, collaboration skills and technical competence. The inquiry process had various phases where the students took turns working alone (when producing and commenting on research questions and explanations), in pairs (when searching for information from literary sources) and in teams of four (when examining the courtyard plants, explaining observations and presenting the outcomes). Varying tools of the web-based collaboration system (a brainstorming tool, discussion forums, co-editable documents etc.) as well as an interactive whiteboard (IVB) were used for documenting and sharing ideas and contributions, depending on the nature and requirements of the activity in each phase. *Teacher 1* conducting the unit was a male teacher with 20 years of teaching experience, 19 of them at the current school. He had used ICT for 20 years in teaching, 24 years altogether. He was the teacher in charge of ICT issues at his school. He had been an active developer of ICT in education also outside the school for several years, working as a teacher trainer and scriptwriter of educational materials.

In *Case 2*, titled 'School children's Web journal', 5th grade primary school pupils (11-12 years of age) created stories for a digital school journal. About one third of the pupils had special education needs. The project lasted for six weeks, with two lessons at school each week, twelve lessons in all. The journal was published with the Magazine Factory program (http://www.mazinefactory.edu.fi), which is a free publishing application for schools that simulates professional publication practices. Besides that, the Microsoft Notepad application, digital cameras and IVBs were used. The aims of the unit were to become acquainted with virtual publishing and editorial tasks as well as to develop skills for creating digital material through story writing, taking pictures with a digital camera and pasting pictures and text in the publishing tool. The pupils were given the responsibility for creating stories in pairs or groups. They decided the themes, wrote the stories, took digital pictures and made proposals for the layout. Moreover, they commented on each others' drafts in the middle of the process and together evaluated all the outcomes and the working process at the end of the unit. *Teacher 2* conducting the unit had 26 years of teaching experience, two of them at the current school. He had used ICT for 15 years in teaching, about 17 years in all. He was an active developer also outside the school and had belonged to an ICT expert teacher team in his city for several years, training other teachers to use various ICT tools in teaching.

Data Collection

All the lessons constituting the pedagogical units conducted by the two teachers were observed and videotaped by one or two researchers. The teachers were shortly interviewed before and after each session about that particular lesson. In the pre-interview, the questions were about the goals, plans and expectations concerning the lesson and the usage of technology. In the post-interview, the teachers were asked whether the goals and plans were achieved and what they would do differently next time. All the outcomes produced by the teachers and the pupils during the process in the virtual working spaces and the Web were collected. The training materials for the FICTUP project (the written pedagogical scenario and related videos) were co-constructed together by the teachers and the researchers, based on the collected data and draft plans written by the teachers.

Data Analysis

The qualitative data analysis method used in the study was based on the approach introduced by Chi (1997). The primary data were the videotaped lesson observations because we wanted to focus on the teachers' actual practices in the classroom. All the videotapes were examined by the principal investigator of the study, and those sections revealing a design solution or scaffolding activity of the teacher were categorized qualitatively using the components of the Pedagogical Infrastructure Framework into whether the activity focussed on technical, social, epistemological or cognitive support. The detailed video data analysis was conducted using the Atlas.ti program. The main distinctive phases in the pupils' working process in each unit were defined based on the classroom observations and the written scenario. The distribution of the pedagogical infrastructure elements visible in the practices was then counted for each phase in order to get an overview of the teachers' pedagogical designs. Other data were used as a complementary source for interpreting the classroom activities and providing examples of the practices and reflections of the teachers.

Results

The results are presented separately for each case, and in both cases the ways that teachers designed and scaffolded the pupils' learning efforts in the units are unfolded. First, the distinctive phases of the process are shortly described, then the distribution of the pedagogical infrastructure elements in each phase is presented with a diagram. Sophisticated examples of the teachers' pedagogical practices in technology-enhanced collaborative learning are presented in a table, structured according to the four central pedagogical infrastructure elements. Finally, the main issues from the teachers' self-reflections after the lessons are summarized.

Pedagogical Practices in Case 1: Exploring Growth Factors through Inquiry

In Case 1, the teacher structured the working process in phases that for the most part followed the Progressive Inquiry model, which had been adopted by the teacher several years before in a previous development project (Lakkala et al., 2005). The teacher also presented the model to the pupils in a visual form (see FICTUP Pedagogical scenario, 2010a). The pupils' concrete activities in each lesson were shaped by these phases. The following phases of the process were identified:

1. *Creating the context*, including orientation to the topic, introduction of the progressive inquiry model and demonstration of the working phases in the Web-based collaboration system.
2. *Generating questions and forming the research groups*, where pupils generated questions about growth factors with a brainstorming tool. The questions were examined together using the IVB, and four research groups were formed based on them (light, water, warmth and soil/nutrients).
3. *Writing explanations of the research questions,* where pupils wrote explanations that answered their group's research question in a discussion forum and commented on other group's explanations.
4. *Making and documenting observations*, including field work where pupils measured the length of plants in two areas in the school courtyard. The results were written down in the pupils' notebooks.
5. *Interpreting and explaining observations*, where groups constructed a table about their observations in the groups' Web document, compared the length of plants in two areas and wrote interpretations of the differences. Then the pupils commented on the explanations of the other groups in a forum.
6. *Adding explanations from information sources*, where the pupils first in pairs sought new information about their research topic from a text source on the Web and then added relevant explanations to their group's Web document as a group.
7. *Giving presentations*, where each group presented their results in front of the class by explaining the content of their Web document (topic, results, interpretations and new knowledge found) with the IVB.

In all, 184 separate sections representing the pedagogical design solution or scaffolding activity of Teacher 1 were chosen from the 10 lessons of Case 1. The sections were distributed in the four support categories in the following way: 23% technical, 25% social, 35% epistemological and 17% cognitive. Figure 1 presents the distribution of these activities into categories in each phase of the process.

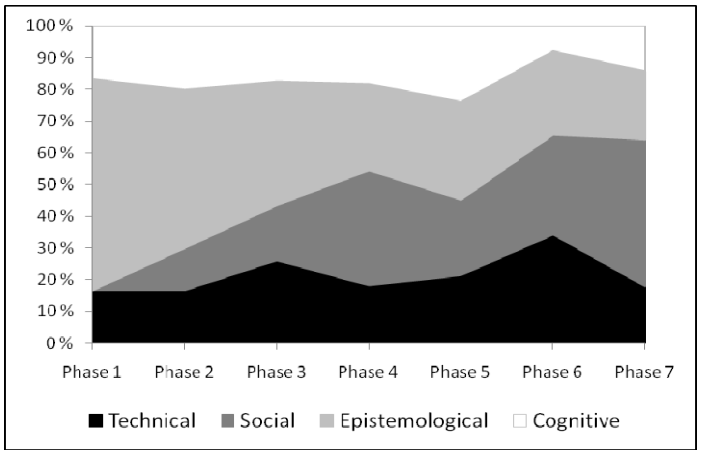

Figure 1. The Relative Distribution of the Pedagogical Infrastructure Elements in the Phases of Case 1.

Figure 1 shows how the focus of the designed activity in the first and second phases of the process was more on epistemological issues concerning the topic of inquiry and the research questions. Social issues received more emphasis from the teacher when the pupils started their group work or shifted between working individually, in pairs or in groups. What is noteworthy is that the roles of all four supporting elements were quite evenly distributed throughout the process. In Table 1 we have chosen examples of pedagogical practices by Teacher 1, which can be regarded to represent sophisticated, expert-like practices that are good models for other teachers. Separate examples are presented for overall design solutions and for scaffolding activities. When a practice relates to a specific phase of the process, the phase is mentioned in parentheses.

According to the post-interviews after the sessions, the teacher was generally satisfied with his design of the unit and the students' engagement. He did not do much evaluation of whether the process was successful or not, but carefully and critically analyzed which practices were challenging for pupils and in which skills they still required more guidance and practice (e.g., asking questions, making a table, understanding written instructions, sharing responsibilities in group work). The teacher thought that the same design could well be applied to various age groups and topics, if the participants' competence level is taken into account.

Table 1: Examples of sophisticated pedagogical practices in Case 1.

Support	Overall design	Scaffolding
Technical	The introduction of versatile tools relevant for the specific activity in different phases (brainstorming tool, discourse forums, Web document, IVB etc.).	Giving advice about advanced practices for using various, appropriate tools for different purposes and for managing multiple working spaces.
Social	Versatile combinations of individual, pair and group work according to the process phase and nature of the activity. Explicit demands for groups to combine individual results and make a common report page and presentation.	Training good collaboration practices and reminding groups to follow them throughout the process. Constantly taking care that pupils take turns in tasks carried out in groups with shared resources (e.g., one computer).
Epistemo-logical	A relatively complex, overarching inquiry task simulating scientific work. Groups were formed on the basis of the pupils' own inquiry questions. (P2) The use of various information sources: videos and texts in the Web, guide books, observations.	Encouraging wild idea generation and the comparison of viewpoints. (P2) Requiring improvement in discourse quality because of pupils' unclear or irrelevant messages in the forums. (P5)
Cognitive	The modeling of inquiry strategies with a visual progressive inquiry cycle. Explication of the process progression through cumulative written guidelines in the virtual spaces.	Repeatedly connecting the phases of the inquiry cycle to concrete ongoing activities. Teaching pupils to read and follow written guidelines instead of leaning on the teacher. Stopping the process for self-evaluation and corrective actions when needed.

Pedagogical Practices in Case 2: School Children's Web Journal

As in Case 1, in Case 2 the teacher modeled the progression of the publishing process by dividing it into clear sub-tasks and drawing a picture of it on the blackboard. All the pupil groups did the tasks in the same order, but they worked at their own pace. During the same lesson, one group might still be writing their story while another group was already taking photos. Therefore, the teacher did not often give general instructions to the whole class; instead, he guided each group separately in the new procedures when they reached a new phase in their process. The following phases of the process were identified:

1. *Orientation to the task* by examining existing journals and forming editorial groups.
2. *Brainstorming of article topics* first in groups and then in a whole class discussion. After choosing a topic, the groups planned the content of their story by constructing a mind map in paper.
3. *Creating articles through process writing*, including multiple revisions of article drafts in groups and reciprocal feedback sessions between two groups.
4. *Taking photographs for the articles*, where the groups took photographs for their journal stories after the teacher had instructed them in the use of a digital camera. Each group also moved the photographs from the camera to a computer and further to the publishing tool with the teacher's support.
5. *Continuing the writing and publishing of articles*, where the groups finalized their stories, after which the teacher guided each group as they combined their story texts and photos into an article in the school's Web journal using the publishing program.
6. *Self-evaluation of the process and outcomes* included a session where pupils evaluated both the articles and the whole working process first in groups and then in a whole class discussion. Each pupil was also asked to evaluate his or her own contribution to the process.

In all, 261 separate sections representing a pedagogical design solution or scaffolding activity of Teacher 2 were chosen from the 12 lessons of Case 2. Because each pupil group worked at their own pace in the process, the chronological progression of the teachers' pedagogical activities cannot fully be presented according to the process phases. Most groups also worked on the writing project during their leisure time between the weekly lessons, which partly explains the variation in the process progression. The sections were distributed among the four support categories in the following way: 31% technical, 21% social, 25% epistemological and 23% cognitive. In Figure 2, the process is divided into weekly sessions consisting of two lessons, and the various process phases that separate pupil groups focused on during each session is mentioned in parentheses.

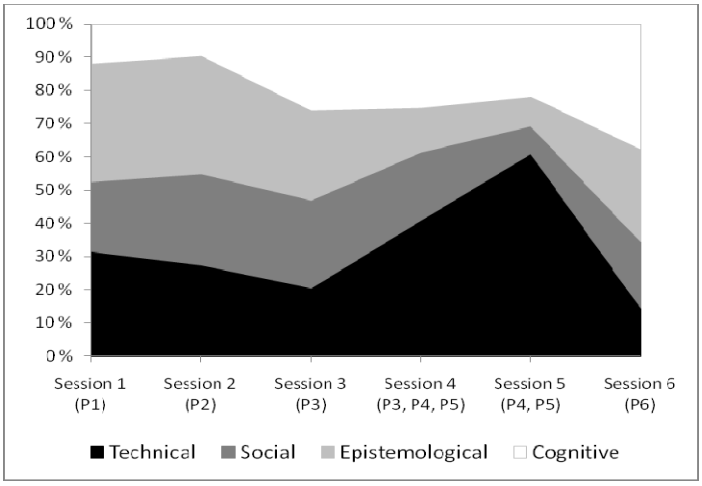

Figure 2. The Relative Distribution of the Pedagogical Infrastructure Elements in the Sessions of Case 2.

Figure 2 reveals that in the Web journal case, the support for learning technical competencies was substantial, especially in the middle phases when pupils learned to use digital cameras and to transfer material from the writing application and the cameras to the publishing program. Epistemological elements were emphasized at the beginning of the writing process when pupils brainstormed the content of their stories, whereas the teachers' structuring of cognitive or metacognitive elements increased towards the end of the process through promoting evaluative and self-reflective activities. Support for social activities and collaboration was less evident, but the teacher did made it clear in all situations whether pupils were supposed to work in groups or as a whole class, and which pupils or groups were supposed to work with each other. In Table 2 is a selection of exemplary pedagogical practices by Teacher 2, which can be regarded as representing sophisticated, expert-like practices that are good examples for other teachers. Separate examples are presented for overall design solutions and for scaffolding activities. When a practice relates to a specific phase of the process, the phase is mentioned in parentheses.

In the post-interviews after each session, the teacher evaluated that the goals of the unit were achieved well; in some phases pupils managed even better than the teacher expected, and the technology did not cause problems. Some pupils appeared to require more guidance in engaging in group work and in coordinating activities done at home and at school. The peer-commenting activity was tested by the teacher for the first time as part of the writing process, and he thought that its design and scaffolding required improvement. Overall, the teacher believed that after finishing the unit, the pupils were able to continue writing stories in the school's journal on their own.

Table 2: Examples of sophisticated pedagogical practices in Case 2.

Support	Overall design	Scaffolding
Technical	Introducing versatile tools according to the nature of the activity (Notepad, Magazine Factory, digital camera, IVB)	Guiding new technical skills for each group when they needed them in their own process, not in a general manner.
Social	Directing the students to make stories in pairs or groups. (P1) Directing the groups to evaluate each others' drafts through peer reviewing. (P3) Smoothly combining group and whole class discussions both in the brainstorming and in the evaluation phase.	Emphasizing to pupils in the final evaluation session that in group work, the whole group should take care of each member's turn and contribution in doing a collective activity. (P6)
Epistemo-logical	The whole process simulated the practices of a professional editorial staff. The pupils were allowed to choose the topic for their stories according to their own interests. (P2)	Explaining to pupils that they are documenting their school's preserved history with the stories. Repeatedly encouraging the pupils to be creative and to make the stories richer and more interesting.
Cognitive	Explicating the phases of a publishing activity through a visual process scheme. Organizing an evaluation session at the end in which the final stories, group work and individual contributions were evaluated by the pupils.	Regularly speaking with each group about what phases of the process they have finished and what phases are remaining, and asking the groups to report the status of their work.

Discussion and Conclusions

In the present study, the classroom practices (pedagogical design solutions or scaffolding activities) of two elementary school teachers who are experienced in the pedagogical use of ICT were analyzed in detail to exemplify sophisticated ways of using ICT in school education. The classroom practices were categorized according to their supporting role in the pedagogical infrastructure: technical, social, epistemological or cognitive (Lakkala, 2010).

In both of the units, one goal defined by the teachers was to develop pupils' *technical* competencies. In the units, the young pupils were taught quite challenging procedures in combining the usage of various technological applications, and the ICT usage was embedded in a meaningful context of a goal-oriented complex task. The teachers' approach complied with the opinion shared by many researchers (Pruulmann-Vengerfeldt, Kalmus & Runnel, 2008; Tierney, Bond & Bresler, 2006; Erstad, 2010) that digital competence is developed best in settings that include rich and integrated use of various technical tools as well as a wide range of activities that are based on complex, open-ended tasks such as product development, the solving of multidisciplinary problems, project work or collaboration.

Both teachers gave a large amount of responsibility to the pupils themselves in their group task, but also constantly monitored their progression, and when they good reasons, required corrective actions from the pupils if the criteria of the work were not met. It appears that very high-level and clear criteria both for *social* behavior (shared responsibility and negotiations, a common goal, proper commenting practices etc.) and for the *epistemological* quality of the work (a focus on concrete outcomes, the relevance of the produced questions and explanations, quality requirements for publishable texts etc.) were directing the teachers' design solutions and scaffolding activities throughout the process. In the classroom situations, these experienced teachers constantly and very conscientiously took care of those issues that they believed to be important in the designed activity.

Both of the teachers also promoted the pupils' self-regulative competences concerning the working practices through various sophisticated methods representing *cognitive* support. White and Fredriksen (2005) divided methods supporting metacognitive development into conceptual tools (e.g., guidelines, models, templates or software scaffolds) and metacognitive tasks (explicit tasks for planning, monitoring and reflecting one's own activity). In both units, the teachers provided the pupils with *conceptual tools* by modeling the working strategies and process progression through using visual modeling, writing systematic guidelines and phase descriptions, explicating the goals for the activity or emphasizing the criteria for high-level ways of working. *Metacognitive tasks* were explicitly included as essential working phases in both units, such as evaluating and improving one's own writings, commenting on others' productions, or having group-level and whole-class discussions in which the outcomes and working practices were reflected on and assessed together.

One important pedagogical characteristic in both of the units investigated was that the activity designed by the teachers was based on a holistic and goal-oriented working model that created a meaningful context for separate sub-activities and lessons. What is noteworthy is that the working models that the processes followed did not represent any pedagogical model that focuses on *learning* (such as the models of collaborative learning, problem-based learning or discovery learning). Rather, they were models simulating authentic *professional* practices in some field: in Case 1, scientific inquiry practices, and in Case 2, professional publication practices. For instance, Chinn and Malhotra (2002) criticized the practices of typically scientific reasoning being taught in schools through 'simple inquiry tasks' instead of 'authentic scientific inquiry tasks'. The teachers of the present study trusted in the pupils' ability to conduct a complex, challenging working process including various technical, social and epistemological elements, which is even more significant taking into account the nature of the pupil groups: very young pupils in Case 1, or a large proportion of pupils with special needs in Case 2.

The analysis revealed that the experienced teachers planned well-organized activities in which various elements of a pedagogical infrastructure were closely attended to and smoothly integrated. The study confirmed our previous result (Ilomäki et al., 2006) that technological skills as such are not sufficient for teachers to develop their pedagogical practices with ICT, but other competencies for planning, organizing, structuring and guiding pupils' learning activities with ICT are needed. The results can be used to complement current training materials presenting experienced teachers' practices with guidelines where essential aspects of the practices are unfolded and emphasized. A research aim for the future is to apply this approach to other situations and test the effectiveness of the materials in teacher training courses, collegial tutoring practices and self-study settings.

References

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

Chi, M.T.H. (1997). Quantifying qualitative analyses of verbal data: A practical guide. *Journal of the Learning Sciences, 6*(3), 271–315.

Chinn, C. A., & Malhotra, B. A. (2002). Epistemologically authentic reasoning in schools: A theoretical framework for evaluating inquiry tasks. *Science Education, 86*, 175–218.

Erstad, O. (2010). Educating the digital generation. *Nordic Journal of Digital Literacy, 1*, 56–70.

FICTUP Pedagogical scenario (2010a). Exploring growth factors. Applying inquiry learning and virtual forums. Retrieved March 3, 2011, from http://www.fictup-project.eu/index.php/Exploring_growth_factors._Applying_inquiry_learning_and_virtual_forums

FICTUP Pedagogical scenario (2010b). School children's Web journal. Publishing with Magazine Factory tool. Retrieved March 3, 2011, from http://www.fictup-project.eu/index.php/School_children%E2%80%99s_Web_journal._Publishing_with_Magazine_Factory_tool

Cuban, L., Kirkpatrick, H., & Peck, C. (2001). High access and low use of technologies in high school classrooms: Explaining an apparent paradox. *American Educational Research Journal, 38*, 813–834.

Gibson, S., & Oberg, D. (2004). Visions and reality of Internet use in schools: Canadian perspectives. *British Journal of Educational Technology, 35*, 569–585.

Hogan, K., & Pressley, M. (1997). Scaffolding scientific competencies within classroom communities of inquiry. In K. Hogan & M. Pressley (Eds.), *Scaffolding student learning: Instructional approaches and issues* (pp. 74–107). Cambridge, MA: Brookline Books.

Hyo-Jeong S., & Kim, B. (2009). Learning about problem based learning: Student teachers integrating technology, pedagogy and content knowledge. *Australasian Journal of Educational Technology, 25*(1), 101–116.

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

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.

Kozma, R., & Anderson, R. (2002). Qualitative case studies of innovative pedagogical practices using ICT. *Journal of Computer Assisted Learning, 18*(4), 387–394.

Lakkala, M. (2010). *How to design educational settings to promote collaborative inquiry: Pedagogical infrastructures for technology-enhanced progressive inquiry*. University of Helsinki, Institute of Behavioural Sciences, Studies in Psychology 66. Helsinki: Helsinki University Print.

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.

OECD (2010). *Are the new Millennium learners making the grade? Technology use and educational performance in PISA 2006*. Paris: OECD Publishing.

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

Pedersen, S., Malmberg, P., Christensen, A. J., Pedersen, M., Nipper, S. Graem, C. D., et al. (Eds.). (2006). *E-learning Nordic 2006. Impact of ICT on education*. Copenhagen: Ramboll Management.

Putnam, R., & Borko, H. (2000). What do new views of knowledge and thinking have to say about research on teacher learning. *Educational Researcher, 29*, 4–15.

Pruulmann-Vengerfeldt, P., Kalmus, V., & Runnel, P. (2008). Creating content or creating hype: Practices of online content creation and consumption in Estonia. *Cyberpsychology, 2*(1), 1–8.

Putnam, R., & Borko, H. (2000). What do new views of knowledge and thinking have to say about research on teacher learning. *Educational Researcher, 29*, 4–15.

Smeets, E. (2005). Does ICT contribute to powerful learning environments in primary education? *Computers & Education, 44*, 343–355.

Tierney, R. J., Bond, E., & Bresler, J. (2006). Examining literate lives as students engage with multiple literacies. *Theory Into Practice, 45*(4), 359–367.

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

Yin, R. K. (2003). *Case study research. Design and methods* (3rd ed.). Thousand Oaks, CA: Sage.

Acknowledgments

The research work was partially supported by the Lifelong Learning Programme of the European Union, contract 141929-2008-LLP-FR-COMENIUS-CMP (the FICTUP project). The authors thank the teachers and their pupils for participating in the study.