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The effects of ICT on school: teachers' and students' perspectives

by

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ABSTRACT

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The purpose of this study was to investigate the effects of information and communication technology (ICT) on school from teachers' and students' perspectives. The focus was on three main subject matters: on ICT use and competence, on teacher and school community, and on learning environment and teaching practices. The study is closely connected to the national educational policy which has aimed strongly at supporting the implementation of ICT in pedagogical practices at all institutional levels.

The phenomena were investigated using a mixed methods approach. The qualitative data from three cases studies and the quantitative data from three statistical studies were combined. In this study, mixed methods were used to investigate the complex phenomena from various stakeholders' points of view, and to support validation by combining different perspectives in order to give a fuller and more complete picture of the phenomena. The data were used in a complementary manner.

The results indicate that the technical resources for using ICT both at school and at homes are very good. In general, students are capable and motivated users of new technology; these skills and attitudes are mainly based on home resources and leisure-time use. Students have the skills to use new kinds of applications and new forms of technology, and their ICT skills are wide, although not necessarily adequate; the working habits might be ineffective and even wrong. Some students have a special kind of ICT-related adaptive expertise which develops in a beneficial interaction between school guidance and challenges, and individual interest and activity. Teachers' skills are more heterogeneous. The large majority of teachers have sufficient skills for everyday and routine working practices, but many of them still have difficulties in finding a meaningful pedagogical use for technology. The intensive case study indicated that for the majority of teachers the intensive ICT projects offer a possibility for learning new skills and competences intertwined in the work, often also supported by external experts and a collaborative teacher community; a possibility that "ordinary" teachers usually do not have. Further, teachers' good ICT competence help them to adopt new pedagogical practices and integrate ICT in a meaningful way.

The genders differ in their use of and skills in ICT: males show better skills especially in purely technical issues also in schools and classrooms, whereas female students and younger female teachers use ICT in their ordinary practices quite naturally. With time, the technology has become less technical and its communication

and creation affordances have become stronger, easier to use, more popular and motivating, all of which has increased female interest in the technology.

There is a generation gap in ICT use and competence between teachers and students. This is apparent especially in the ICT-related pedagogical practices in the majority of schools. The new digital affordances not only replace some previous practices; the new functionalities change many of our existing conceptions, values, attitudes and practices. The very different conceptions that generations have about technology leads, in the worst case, to a digital gap in education; the technology used in school is boring and ineffective compared to the ICT use outside school, and it does not provide the competence needed for using advanced technology in learning.

The results indicate that in schools which have special ICT projects (“ICT pilot schools”) for improving pedagogy, these have led to true changes in teaching practices. Many teachers adopted student-centred and collaborative, inquiry-oriented teaching practices as well as practices that supported students' authentic activities, independent work, knowledge building, and students' responsibility. This is, indeed, strongly dependent on the ICT-related pedagogical competence of the teacher. However, the daily practices of some teachers still reflected a rather traditional teacher-centred approach. As a matter of fact, very few teachers ever represented solely, e.g. the knowledge building approach; teachers used various approaches or mixed them, based on the situation, teaching and learning goals, and on their pedagogical and technical competence. In general, changes towards pedagogical improvements even in well-organised developmental projects are slow. As a result, there are two kinds of ICT stories: successful “ICT pilot schools” with pedagogical innovations related to ICT and with school community level agreement about the visions and aims, and “ordinary schools”, which have no particular interest in or external support for using ICT for improvement, and in which ICT is used in a more routine way, and as a tool for individual teachers, not for the school community.

The effects of ICT on school: teachers' and students' perspectives

Abstract

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During my professional career, school, learning, and computers have always been somehow intertwined. In the beginning of the 1980s, as a young teacher working at the ATK-Instituutti, I became fascinated with computers and all the possibilities I could imagine for education. Those pioneer times 1985–95 were very inspiring, and I was lucky to collaborate with several creative and talented pioneers of computers in education, who also gave me possibilities and tasks which widened my understanding. This doctoral thesis would not have been possible without all those practical experiences and without all my dear colleagues in the ATK-Instituutti, Brainware, Dipoli Täydennyskoulutuskeskus, and Koulun tietotekniikkakeskus. The Nordic collaboration in promoting ICT in school during the same period is an important part of the background to this study: we used and developed the so-called Market diagram for designing educational software. Gradually that model started to bother me because of its lack of a conscious pedagogical framework. My big question was whether computers also have some pedagogical function or not, and if yes, what kind of pedagogy do they promote. I consider this question the basis of my scientific work even today. In the beginning of the 1990s I continued to study this issue further in the Open University in the Netherlands with a grant from the European Commission. I was guided by Professor Rob Koper, whose interest in pedagogical frameworks helped me to conceptualise my previous practice-related thoughts and ideas. After that year it was easy, and self-evident that I would start working as a researcher.

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Espoo, 14th September, 2008

Liisa Ilomäki

LIST OF ORIGINAL PUBLICATIONS

- I Ilomäki, L., Hakkarainen, K., Lakkala, M., Rahikainen, M., Lipponen, L. and Lehtinen, E. (2002). Uses of New Technology Across Genders and Generations: Comparing the Development of Students' And Teachers' ICT Skills and Practices of Using ICT. In K. Fernstrom (Ed.), *Proceedings of Third Conference on Information Communication Technologies in Education*. (pp. 539–548). Athens: National and Kapodistrian University of Athens.
- II Ilomäki, L. Does gender have a role in ICT among Finnish teachers and students? Manuscript submitted for publication.
- III Ilomäki, L. and Rantanen, P. (2007). Intensive use of information and communication technology (ICT) in lower secondary school: Development of student expertise. *Computers and Education*, 48, 119–136.
- IV Ilomäki, L., Lakkala, M. and Lehtinen, E. (2004). A case study of ICT adoption within a teacher community at a Finnish lower-secondary school. *Education, Communication and Information*, 4, 53–69.
- V Ilomäki, L., Lakkala, M. and Paavola, S. (2006). Case studies of learning objects used in school settings. *Learning, Media and Technology*, 31, 249–267.

1. INTRODUCTION

The overall theme of this study, *the effects of information and communication technology (ICT) on school*, is a complex object to investigate: several factors influence it, it is closely connected to society, the political background and decision-making, and it is deeply dependent on the previous history of ‘school’ and the values and norms of education. The school is a workplace for teachers and other professionals, providing a unique learning environment for pupils. In this study the approach to ‘school’ is to consider it in its totality by investigating it from several perspectives in order to reach essential issues concerning the richness of ‘school and ICT’.

In the beginning of the implementation of ICT there were optimistic beliefs about profound changes in teaching and learning practices, among both educational researchers and policy-makers. Although there have been several development projects, experiments and pilot studies on using ICT in school, the studies about long-term and deep-going effects of ICT are still few (Kozma, 2003a; Venetzky & Davies, 2001). Altogether 15–20 years’ experience in classroom and school practices, as well as research evidence show that *something* changes in education when information and communication technology (ICT) is used (e.g. Bayraktar, 2000–2001; Korte & Hüsing, 2007; Kozma, 2003a) but the content, the direction and the depth of the change are still under discussion and remain issues for investigation. The effects of ICT have often regarded as a positive change, and as if change always means improvement. However, ‘change’ and ‘improvement’ are not synonyms, and the changes, when using ICT, are not merely beneficial or expected; similarly as Rogers wrote about unexpected consequences of innovations (1995). In this study, the theme was investigated by using different points of view of the main actors in school, i.e. teachers and students¹. In addition, various research methods were applied based on how well they met the research topic and objects.

Investigating ICT-related issues is strongly time-related. Distribution, use, and practices, as well as individuals’ ICT skills change rapidly as new applications replace old ones, and new tools and applications come on the market every month. ICT has quickly, within the last ten years, become a part of ordinary life. Research data inevitably describe a past situation. During the years of the sub-studies of this dissertation, the nature of technology has changed from a technical connotation towards communicative connotation, mainly because of the development of new applications in the Internet. This has increased the use of ICT dramatically. Similarly, the access to ICT has improved among students and teachers, and both at home and at school. One of the consequences is the change in how ICT skills are understood. They were first defined as merely technical skills, e.g., the ability to use a word processing

¹ Parents are an essential influencing factor in school, and especially their interest and motivation has been in using technology; mainly in order to increase the use in education (e.g. Koivisto et al. 2001). In this study the role of parents as actors of school is considered only implicitly, in Study IV.

application or a database application, sometimes even programming skills, e.g. in using Pascal-programming language. Nowadays the skills are defined as digital competencies in a wider context.

For a school researcher it is a challenge to find general, more permanent phenomena related to educational technology instead of concentrating on temporary details, e.g. on some technical applications which come and go. In this study, this challenge was answered by combining the various issues related to technology with general issues, such as gender and generation differences, the nature of expertise, classroom practices, and school change. These formed the framework of the study, concerning the effects of ICT in school. In this study, I refer to the ecological approach, which compares school to an ecological system “to holistically capture the dynamic nature of technology use in school settings” (Zhao, Lei & Frank, 2006, p. 138). I use the concept ‘affordance’ (Gibson, 1979), which has an ecological background; Basalla (1987) investigated the history of technology by using ecology as a metaphor, and later on Nardi and O’Day (1999) investigated the new forms of technology with an ecological framework. I share their understanding of the need and the importance of investigating ‘school’ and ICT holistically, and the ecological approach is a fruitful tool for understanding the dissemination of technology. In the sub-studies, the following concepts are discussed:

- Study I: ICT competence
- Study II: ICT competence, digital divide
- Study III: Adaptive student expertise, learning environment
- Study IV: School change, teacher community, learning environment, pedagogical practices, teacher’s competence
- Study V: Learning object, affordance, pedagogical and knowledge practices, teacher’s competence

In this study ‘information and communication technology’ (ICT) and ‘information technology’ are used as synonyms. These are both commonly used concepts referring to computers, the Internet and the digital network, as well as other digital devices and various digital applications used with these tools. ‘Information technology’ was commonly used before the extensive development of the Internet, but recently it also includes Internet applications (see also the definitions in http://en.wikipedia.org/wiki/Information_technology). By concept ‘technology’ I refer to a more general idea of all possible tools and applications, not even existing yet.

In the introduction I will go more deeply into some of the themes investigated in the sub-studies. First, I will connect the world-wide interest in applying ICT in education to societal aims and expectations in order to shed light on the contradictory results and practices of ICT use. I will also consider the Finnish national educational policy. Second, I will introduce the theoretical background to learning, to school as a community, the fluid concept of ICT competence, and the role of technology as a tool. Finally, I will consider the different views on the change processes in school, caused by the use of ICT, because it is an essential factor behind the successful ICT pilot schools and the less successful “ordinary” schools. In the introduction I will connect the results of the sub-studies with the general results of ICT use both in well-supported ICT pilot schools, investigated using case studies, and in ordinary schools, studied mainly by using statistically analyzed questionnaires.

2. GOALS OF THE STUDY

The overall focus of this dissertation study was on the effects of ICT in school, and I wanted to investigate the topic widely from different perspectives and levels, both from students' and teachers' perspectives, as well as from the classroom and the school level. What then are the novel phenomena when ICT is implemented in teaching and learning practices? To answer this, I have felt like a traveler, following Kvale's (1996) suggestion of a metaphor for an ethnographic researcher: I have had the privilege to observe several teachers and students in their everyday life in schools and in classrooms as they were implementing new pedagogical practices and technologies. In addition to these case studies, which were mainly based on data from observations and interviews, the dissertation consists of statistically analyzed surveys, which were conducted in order to find out the distribution of various aspects of ICT among Finnish teachers and students.

Implementing ICT into education involved several interesting phenomena which had not been fully examined or explained in previous studies when I started to conduct the sub-studies:

- First, issues related to technology: Do students and teachers have a good access to ICT? How do genders and generations differ related on ICT? What is the special ICT competence that some (boys) seem to have?

- Second, issues related to activities in classrooms using ICT: Is teaching changed? What is the actual role of teachers and students? What really changes? Is ICT as a catalyst for change or not?

- Third, issues related to effects and consequences of implementing ICT for school and for teaching community: What kind of effects there will become? What kind of practises among teachers develop? How sustainable are changes? How does school reality match to the various expectations of society and parents? These unclear issues have guided this study programme, and they were a basis for the concrete goals, presented in chapter 4.2.

3. IMPLEMENTING ICT INTO EDUCATIONAL PRACTICES

3.1. Education for the information society?

The use of information technologies in various fields of society indicates the emergence of the ‘information society’. Information / knowledge society is not a stable concept; it is strongly policy-oriented, and its content also has national peculiarities. The concept ‘information society’ has recently been replaced by ‘knowledge society’, and Brown and Duguid (2000) questioned whether this reflects that something is lacking in the first concept that is caught in the second one. They claim that knowledge, on the contrary to information, entails a knower; appears harder to detach than information, and entails the knower’s understanding and a degree of commitment. From the learning point of view, ‘knowledge society’ is a far more attractive goal than ‘information society’². Hargreaves (2003) presents a knowledge society which has its basis in the knowledge economy. From that point of view, the knowledge society has three dimensions: first, it comprises an expanded scientific, technical and educational sphere; second, it involves complex ways of processing and circulating knowledge and information in a service-based economy; and third, it entails basic changes in corporate functions to enhance continuous innovation in products and services by creating systems, teams and cultures that maximize the opportunities for mutual, spontaneous learning.

The information society is based on the belief that knowledge is the driving force for technology development and thus also for economic growth; the knowledge work and knowledge workers form a relatively large proportion of the employment. For the knowledge economy it is not only a question of whether people can access information but also how well they can process this information (Hargreaves, 2003). Education becomes essential to answer the needs of technology and society, and it presumes, e.g. the democratization of higher education (Waters, 1998). Education is regarded as the means to meet the ICT revolution, but also a means to keep pace with the continuing ICT development.

The rapid distribution of information technology in almost all areas of society has become true also in education, and all OECD countries have invested heavily in ICT for educational use (OECD, 2004), mainly because, as Hargreaves (2003) says, the OECD has been one of the prime movers behind new knowledge economy initiatives. Worldwide, the utilization of information technology in education has been regarded an essential factor for economic growth, although the educational practices and structures and the economic growth have a complex and reciprocal relationship, as Kozma (2005) describes them comparing Finland, Hong Kong and Egypt regarding their solutions to applying technology in education. Further, it is difficult to measure the overall benefit of ICT investments (OECD, 2004). This interest in information

² In the text, I use the concept which is used in the text referred to. In Finnish, ‘tietoyhteiskunta’ includes both meanings. In English translations, the term used is often ‘information society’.

technology is often even enthusiasm; Selwyn (2002) calls it for ‘techno-romance’. Anyhow, the role of information technologies in educational development is established – even to the extent that it is believed there would be no educational development without ICT (Nivala, in press; Selwyn, 2002; Waters, 1998).

In policy discussions, the arguments for using ICT are often based on promoting the information society, which sets demands for improved teaching and learning. In the information society, the new jobs require new skills, namely, skills of interaction with the new technology (European Commission, 1998), but also more general skills (Kozma, 2005). ICT has also been regarded as a strategy to improve teaching and learning and to implement and facilitate the new pedagogy of the information society (Cuban, Kirkpatrick & Peck, 2001; OECD, 2004; Voogt & Pelgrum, 2005). This also has practical consequences. Already in 1996, the European Commission emphasized the need to exploit new ICT in education and to achieve this, it was necessary to target teachers (and trainers) in introducing ICT into education, and to link schools into the full networking potential of the information society (European Commission, 1998). In the same year, in the USA, President Clinton laid out four similar goals: computers accessible to every student, classrooms wired to one another and to the outside world, educational software to be integrated with the curriculum, and teachers to be ready to use and teach with technology (Cuban, 2001).

Researchers’ expectations for technology at the end of the 1980s and at the beginning of the 1990s arose from the severe criticism by “constructivist” researchers against “school learning”; there was a gap between informal and formal learning (Resnick, 1987). Students should learn through authentic activities and real life contexts, in which knowledge is used to solve ill-defined and complex problems (e.g. Bereiter & Scardamalia, 1993; Brown, Collins, & Duguid, 1989; Bruer, 1993; Resnick, 1987). As computers and information and communication technology became more user-friendly, more efficient and cheaper, it awoke interest among educators to pass on theoretical ideas by using ICT in the classroom. Technology was thought to serve a dual function: it was thought to provide the tools for the realization of learning-as-construction, as well as for the social process of meaning appropriation, and it was thought to offer novel opportunities for novel learning activities and ways of teaching, which, in turn, would require novel psychological insights (Salomon, 1996; Salomon & Ben-Zvi, 2006).

According to Cuban (2001), the expectations in the past were to make schools more efficient and productive, to transform teaching and learning into an engaging and active process connected to real life, and to prepare young people for future workplaces. Lehtinen (2006) described the past expectations as utopias, the entities of strong positive expectations about ICT in education, which were expected to shake up teaching. He found six utopias: the utopia of the tireless and individual trainer, the utopia of the intelligent tutor, the utopia of micro worlds, the utopia of multimedia, the utopia of virtuality, and the utopia of collaborative learning. As Lehtinen stated, there is not yet convincing empirical evidence to support the fulfilment of any of these.

3.2. The national interests to apply ICT in education

This study is conducted in Finnish schools, and the results, naturally, reflect this societal and educational context. In Finland, education is appreciated, and is regarded as one of the key factors of the well-being, for improving social and economic status; Arinen and Karjalainen (2007) concretize this by saying in the report of Programme for International Student Assessment (2005) that every Finnish home has a clear message for the next generation: “If you want to succeed, educate yourself” (p. 71). There is a commonly accepted, conscious aim to give everyone a high-level, free education, independent of social background. Similarly, the teaching profession is appreciated, and teachers’ professional expertise is high; they have a university-level teacher training. The results of Finnish education are shown to be very high on a worldwide scale in PISA comparisons. In addition, the societal conditions support education. Finland is a Nordic welfare state, which means an egalitarian country with a relatively even income distribution, low class distinctions, and relatively high social cohesion, with an exceptionally strong technological emphasis (Ylä-Anttila, 2005). This means, e.g. (still) a rather stable and safe social climate and equality between schools; the division between “good” and “bad” schools is not (yet) true, and the level of educational outcomes is even between schools, compared to several other countries (Arinen & Karjalainen, 2007). Finnish research, however, shows that in urban centres the school differentiation, based on students’ evaluated outcomes, is widening. There are mainly two reasons for this development: the urban structure creates new suburbs with inhabitants of lower socioeconomic status, which correlates with the level of students’ outcomes (lower than in the old, respected schools in the city centres). The other reason for the differentiation trend is parents’ choices of a school for their children: the higher socioeconomic status parents have, the more willing they are to choose a “traditional”, respected school in the city centre instead of the closest local school (Kuusela, 2006). As a result, in these popular schools, the level of parents’ socioeconomic status is higher than expected according to the student catchment area of the school (Seppänen, 2004).

In Finland, the pioneer work for implementing computers in teaching and learning practices was started by inspired teachers and educational developers from the mid-1980s. The technical infrastructure in schools and classrooms was naturally still limited and often based on special arrangements, e.g. on collaboration with a computer company. Teacher organizations, especially those of mathematic and Finnish language teachers, showed interest in bringing computers into education, and they organized small development project and teachers’ in-service training. There also arose a lively collaboration between Nordic countries in educational software development and production, which was financially supported by the National Board of Education. On a large scale, ICT-related educational applications were mainly implemented on the national level several years later, during the 1990s (Bollerslev, 1998).

After a severe economic recession at the beginning of the 1990s, Finland invested strongly in information technology. The information society became a conscious aim of the government, as it launched the first national information society strategy in 1995 (Ministry of Education, 1995). From then on, there has been a national consensus on

the importance of technology, and, e.g. in 2003, an extensive national four-year programme “Information Society for All” is a kind of Finnish Model for building the information society. Knowledge is regarded as a driving force in economic growth and transformation, similarly as elsewhere, and there is a strong commitment to education as an essential factor contributing to a competitive edge and well-being (Ylä-Anttila, 2005). The Ministry of Education has had an official strategy for enhancing the use of ICT in education since 1996 (Ministry of Education, 1995; 1999; 2004). After the third official strategy for the years 2004–2006 (Ministry of Education, 2004), no overall national strategy was created and it was replaced by special programmes, which concentrate on certain limited areas.

The first national strategy in 1995 emphasized the technological infrastructure but also the importance of information society skills that would be achieved by integrating information technology with other subject domains. It also emphasized the need to improve teaching, the use of modern teaching methods and learning material, as well as networking (Ministry of Education, 1995). These aims were also extensively evaluated in a national governmental evaluation project (presented in Sinko & Lehtinen, 1999). Castells and Himanen (2001) estimated this first five-year period by proposing that the technical network infrastructure had been carried out especially well, while in other aims, although commonly accepted, the achievements were less evident. The later strategies of the Ministry of Education (1999; 2004) have promoted extensive teacher in-service training, financing of the technological infrastructure (e.g. by giving local municipalities and schools funding for buying computers and other equipment and building network connections), and the creation of digital learning material. The strategies have relied to a great extent on computer networks as means of learning and teaching. These central-level visions and aims have been put into practice mainly by the National Board of Education; it has, for example, supported the development and production of digital learning material and the setting up of a virtual school, which offers various services to schools to use virtual courses in their own work. At municipal level, several main cities had their own strategies for implementing ICT in education, the first being the City of Helsinki (described in Ilomäki & Lakkala, 2003), and later on also the City of Espoo.

As a result of national choices and decisions, Finland has a strong national policy commitment to supporting the emerging use of ICT, and various administrations from the Ministry of Education to individual municipal organizations have created projects for promoting the use of ICT in education. Kozma (2005) states that the background for using ICT in Finland is in transforming education, as well as other areas of society. The national policy strongly supports the ICT implementation in educational practices, and schools on the whole have adequate technical resources, which are both necessary and important factors for successful innovative practices (Yuen, Law, & Cow, 2004), but not yet sufficient factors. Nivala (in press) concluded in his analysis of Finnish official educational strategies and documents that the meaning of the ‘information society’ is often reduced to the economic, to ensure the economic competitiveness of an individual as well as of society, very like elsewhere in international policy. Nivala also sees economic and technological determinism in the Finnish documents; the

information society and technology are answers to international competitiveness and they have to be accepted as such; there is a continuous trend to present technology as a common solution to every problem and challenge in education.

3.3. Paradigm shift and ICT

As described above in chap. 3.1., the leading researchers on education and on educational psychology were interested in improving learning with computers, and they represented variations of “constructivism”. When starting to do the field work for Studies III and IV, a general constructivist zeitgeist guided me; that was also the pedagogical basis of Studies I and II. In Study V, the pedagogical framework was, further, influenced by the discussion of three metaphors of learning (Paavola et al., 2004). In the following, the basis of the theoretical framework is briefly presented.

The constructivism-oriented researchers presented strong criticism in the 1980s and the beginning of the 1990s against school learning, as discussed in section 3.1., and a lively discussion arose about the foundations of “constructivism”, together with intensive development work to create computer-based applications that could correct the shortcomings of school learning (see, e.g., Choi & Hannafin, 1995; Scardamalia & Bereiter, 1994; The Cognition And Technology Group At Vanderbilt, 1990). In designing educational technology applications, the theoretical questions of the researchers were framed around teaching and instruction (Brown & Duguid, 1993), which otherwise were less discussed during the early years of constructivism. (See a summary of the technology design principles for the various theoretical frameworks, Choi & Hannafin, 1995.)

Two examples show the intertwined development of pedagogical theory and the related technology. Anchored instruction was especially interested in solving one of the basic shortcomings of school learning, the problem of inert knowledge. Bransford and his collaborators created exploration environments in which students and teachers encountered the kinds of problems and opportunities that experts in the field encounter, and the knowledge that these experts use as tools. (The Cognition And Technology Group At Vanderbilt, 1990). These exploration environments represented “a second level authenticity” compared to the approach of situated cognition in the sense that these environments simulated real-world cases. Bereiter and Scardamalia, pioneers of computer-supported collaborative learning, participated in the discussion on defining new demands for learning and technology by presenting CSILE, the computer-supported intentional learning environment. They presented the following features enhancing knowledge building: 1) balance between public and private, and individual and group knowledge processes, 2) contributions and notifications shared and available for all, 3) source referencing to preserve the author’s idea and to provide historical accounts, 4) storage and retrieval for situating ideas in a communal context, 5) multiple points of entry for users of different ages and levels of sophistication, 6) coherence-producing mechanisms for dealing with information overload, and 7) linked resources providing access to the world’s most advanced knowledge resources (1993; 1994).

For the new learning paradigm, it was important, as Lave and Wenger (1990) wrote, to shift the analytic focus from the individual as a learner to learning as participation in the social world, and from the concept of cognitive process to the more-encompassing view of social practice. Olson and Bruner (1996) introduced the differences between learning paradigms by comparing the various conceptions about learning psychology ('child as a doer, child as a knower, child as a thinker, child as an expert') and their implications for pedagogical practices.

New ways to conceptualize learning emerged to a great extent because of an epistemological change: from objectivism to the construction of knowledge. Knowledge is not seen as an objective entity but constructed, and as any tool, it is a product of the activity, context and culture in which it is constructed and used. Knowledge is created and used in social contexts; it has a strongly social nature (Brown, Collins & Duguid, 1989). Even so-called general knowledge has power in specific circumstances (Lave & Wenger, 1990). There are several truths, not only one (Cognition And Technology Group At Vanderbilt, 1992; Jonassen, 1991), and single perspectives are not false, they are just inadequate (Spiro, Feltovich, Jacobson & Coulson, 1991).

According to the new learning paradigm, learners construct meaningful and conceptually functional representations of the external world (Jonassen, 1991). Learning is strongly situated. As Lave and Wenger (1990) wrote, there is no activity that is not situated; agent, activity and world mutually constitute each other. Learning is a continuous, life-long process resulting from acting in situations; an enculturation process, in which knowledge (= conceptual tool), tools, and attitudes are learned in the context of a community (Brown, Collins & Duguid, 1989). It aims at fostering capabilities for working in real life, solving real-life problems, which are ill-structured, situated, and for which the knowledge for solving them is not known (Jonassen, 1991; 1997). A model for learning is an expert, their knowledge construction processes, and their ways of working and using knowledge (Scardamalia & Bereiter, 1994).

Learning should be organized in authentic settings, because students need not just abstract concepts and self-contained examples – they need to learn to use the conceptual tools of the domain in an authentic activity. In the learning environment, teachers act as practitioners [not as 'content-deliverers']. Authentic activities were defined as the ordinary practices of the culture (Brown, Collins & Duguid, 1989). Authentic learning tasks have real-world relevance and utility, integrate tasks across the curriculum, provide an appropriate level of complexity, and allow students to select appropriate levels of difficulty or involvement. Learning environments should support multiple perspectives or interpretations of reality, knowledge construction, context-rich, experience-based activities (Jonassen, 1991).

Studying in a rich, open and authenticity-oriented learning environment was regarded as demanding for a learner, because constructivist instruction asked students to cope with very complex situations, and because students were expected to take more responsibility for the task management. Students were to work at the zone of proximal

development (Perkins, 1991, referring to Vygotsky, 1978). Metacognitive skills are essential for learning, and research about metacognition has been common for the various constructivist trends; it also became an issue for instructional design (see e.g., Jonassen 1991; Osman & Hannafin, 1992).

The separation from those emphasizing individual cognition was certainly a shift from the existing learning paradigm and it took several years before the new paradigm was gradually accepted (for discussion, see in e.g., Andersson, Reder & Simon, 1997). The various trends were developed further under the umbrella of constructivism; however, they shared several basic ideas (Hay & Barab, 2001). Bereiter (2002) lists as such educational ideas that are already widespread, higher-order skills, teaching for understanding, constructivism [construction of knowledge, understood as the opposite of passive reception of information], authentic problem solving, and lifelong learning.

There are, however, also fundamental differences between various approaches within the previously called ‘constructivism’, especially between those that emphasize individual construction and those that believe in the social construction of learning and knowledge, and are severe critics of constructivism (“what is constructed - ideas, knowledge, learning?”, see e.g., Paavola et al., 2004). Instead of speaking about “constructivism” researchers refer to specific pedagogical approaches and frameworks, such as situated cognition, knowledge building or socio-cultural approaches in general, which have continued the theoretical discussion in order to solve the open issues of “constructivism”.

An essential question has been the role of support for learners in the open learning environments. Scaffolding has been one of the answers to the problems of creating new teaching practices. This has been studied, e.g., by Lakkala and her colleagues. They have studied especially the challenges and obstacles of the open, technology-related learning environments, but also the success of teachers in complex, open technology-based learning environments (Lakkala, Lallimo & Hakkarainen, 2005; Lakkala, Ilomäki & Palonen, 2007). In this dissertation, in Studies IV and V, teacher’s new activities and necessary new competences were investigated.

In the theoretical discussion about constructivism, an essential distinction is made in the relation of an individual and the culture. This is represented by in two educational thinkers, John Dewey and L. S. Vygotsky. Glassman (2001) compared their basic conceptions about learning, individuals and social culture. They both regarded as important the roles of everyday activities and the social environment, and in this sense they are close to each other. Glassman sees their conceptions differing in fundamental issues: for Dewey, the individual is central in learning, for Vygotsky, the social organization is the central agent of change. The role of teacher for Dewey is a less dominant facilitator, whereas, for Vygotsky, the teacher is a mentor who builds activities for the learner, at the zone of proximal development. In classroom practices, for Dewey, the classroom is an inherently social organization and a representative of the larger community, in which a child is a viable change agent. In a classroom, together with other individuals, a child reconstructs her thinking about the situation, in

order to maintain even a partial role as an agent for change. For Vygotsky, the classroom is similarly a representative of a larger social community, but the social community is the change agent in the individual.

These ideas continue to live in the various pedagogical approaches and trends, which are then discussed both on theoretical and practical levels. A good example of such a discussion is the comparison between constructivism and apprenticeship, presented by Hay and Barab (2001). They suggest, based on their empirical analysis, that the difference lies in whether the learning environment has a community-centered (apprenticeship) or a student-centered (constructivism) focus. The community-centered environments focus on supporting the membership of a community; learners participate in the fixed community practices, and they are engaged in activities with well-defined goals and sub-goals. Learner-centered environments focus on learners' developing emergent skills, where goals are ill-defined and success is the development of a high-quality product.

In the theoretical discussion, an essential issue has been the role of learners' collaboration for constructing knowledge, although the role and meaning of collaboration varies, as Hay and Barab (2001) show in their study of a constructivist and apprenticeship learning environment. Bereiter and Scardamalia have had a strong influence on defining the role and the nature of collaboration in learning; they call their approach *knowledge-building*. Bereiter (2002) criticized the situated cognition for not making a clear distinction between the situated knowledge which is inherent in the practices, and the non-situated knowledge which for some groups can be the exportable product of work, and for other groups is the material they work with. He emphasizes knowledge building as a specific activity, separated from participation in situated and authentic activities. The advancement of knowledge is creating and improving conceptual artifacts, and these artifacts will be authentic to the extent that they are things the students can actually use, primarily for purposes of understanding real-world phenomena and texts that refer to them. The core activity of schooling should be to help students build a comprehensive and coherent understanding of the world, and this can be achieved by learning through knowledge building, through solving problems of understanding in domains. (Bereiter, 2002; Bereiter & Scardamalia, 1993). (Hakkarainen, together with his colleagues, introduced a practical pedagogical application of inquiry learning, which is based on knowledge building; see Hakkarainen, Palonen, Paavola & Lehtinen, 2004, chapter 14. The model has become popular among Finnish educators.)

The knowledge-building ideas have influenced my thinking in an essential way. They guided how the learning activities in Study IV were introduced to teachers and discussed with them, and the theoretical framework was used in analyzing the classroom. In that way, knowledge-building also implicitly influenced study III, because the adaptive student expertise was a result of the implemented practices in the learning environment.

Three metaphors of learning, presented by Paavola et al., (2004, see also Hakkarainen et al., 2004), form a continuum in the discussion about knowledge creation and social practices, as well as offering one suggestion to open up the discussion about various forms of “constructivism”. The authors first analyze and compare three models of innovative knowledge communities: Nonaka and Takeuchi’s model of knowledge-creation, Engeström’s model of expansive learning, and Bereiter’s model of knowledge building; all of which emphasize dynamic processes for transforming prevailing knowledge and practices. They then suggest, based on this analysis, *the knowledge-creation model of learning* as an addition to Anna Shard’s (1998) model of two metaphors of learning (knowledge acquisition, participation). The suggested third metaphor encompasses theories emphasizing the collective knowledge creation for developing shared objects of activity, an aspect which was not in the focus of the two previous approaches. In short, “knowledge-creation models conceptualize learning and knowledge advancement as collaborative processes for developing shared objects of activity” (Paavola et al., 2004, p. 569). All three analyzed models have several similarities: 1) they use the dynamics of knowledge creation and the pursuit of newness as a focal starting point; 2) they bring mediating elements to the process of knowledge creation; 3) questions and questioning also have an important mediating role; 4) they regard knowledge creation as fundamentally a social process, and, accordingly, new ideas and innovations emerge between rather than within people; 5) individual activity is also emphasized, in the meaning of individuals acting as a part of a stream of social activities; 6) they stress various types of knowledge; 7) they emphasize the role of conceptualization and the role of making knowledge explicit in innovative processes, and 8) they describe how to organize collaboration for developing shared objects of activity in an innovative way. The interaction takes place through the mediating objects, not just between people

During the process of the last study, Study V, structuring the elements of learning through the three metaphors of learning and the emergence of knowledge-creation metaphor had an important influence on my thinking, and it was used as the background to the analytical framework of Study V.

Findings about effects on learning

Does ICT have effects on learning outcomes? This question has been raised from the beginning of ICT use as one of the most interesting and crucial, but the evidence of the impact of ICT is still inconsistent (Condie, Munro, Seagraves, & Kenesson, 2007). Studies trying to find answers to the question have naturally reflected the contemporary culture and practices of education. Computers, and ICT in general, have mainly been investigated in education as separate issues from the overall learning environment and without a connection to the pedagogical framework. Such examples are studies concerning the technical applications used in ICT, and very often even applications used in various subjects (Tondeur, van Braak & Valcke, 2006).

During the years 1980–95, it was typical e.g. to compare teaching with computers and without, and then analyze the learning outcomes. Computers were thought to take

the role of a teacher as an instructor. Similarly, with drill-and-practice exercises a computer was thought to be a tireless trainer which could provide individual challenges on the topics to be learned. There are also studies in which teachers have evaluated whether the learning outcomes are better with ICT; these studies can give information about general attitudes or expectations, but show less about the true effect of ICT on learning outcomes. Some “snapshot” studies may also show effects on learning, but the results reflect the time when ICT was still quite new in the classroom and the benefits reflect the novelty of the intervention (Condie et al., 2007). There are also some meta-analyses, but the studies about the effects on learning outcomes have not provided consistent results (Bayraktar, 2000–2001). Lowe (2000–2001) summarized the findings on meta-analyses of the years 1980–1994, and they showed, e.g. that computer-based-education positively affected student achievement when compared to traditional classroom instruction, but the results were often more complex: the more studies used in the meta-analysis, the lower the effect size was; the role of the instructor (teacher) was often crucial but this varied greatly, and simulation and tutoring as the types of applications used seemed to be most effective. In a meta-analysis about the effectiveness of CAI [computer-aided-instruction] in science, Bayraktar (2000–2001) found a small positive effect on student achievement in science when compared to traditional instruction. The strongest relationships were found in the length of the treatment, the student-to-computer ratio and the publication year of the study. The latter explained by the Hawthorne effect: the computer as a novel tool brought some extra attraction in the first studies of the meta-analysis. In science, too, educational simulations were the most effective applications, while drill-and-practice exercises even had a negative effect. In a newer meta-analysis about ICT in the teaching and learning of English (Andrews et al., 2007) the authors state that the set of studies was so heterogeneous that a meta-analysis was not possible, and they drew the conclusion that the field of research in ICT and literacy/English is in a pre-paradigmatic state needing both a theoretical framework and new kind of research. These three examples of meta-analyses show how difficult and almost impossible it is to obtain empirical evidence of effects on learning. This is understandable: ICT is not just a tool to be adopted as such in the prevailing situation, but it has effects on several factors, like teachers’ role, teaching practices, students’ collaboration, and learning tasks.

School as a learning organization

The learning organization has been a promising concept in analyzing many kinds of organizations and institutions and their ability to respond to the challenges of the complex environment in which they work. The notion of learning organization refer to "organizations, where people continually expand their capacity to create the results they truly desire, where new and expansive patterns of thinking are nurtured, where collective aspiration is set free, and where people are continually learning how to learn together" (Senge, Kleiner, Roberts, Ross & Smith, 1994, p. 3). Marquardt (1996) approached the learning organization from the information management perspective, and defined it as "an organization which ... is continually transforming itself to better collect, manage, and use knowledge for corporate success" (p. 19). Marquardt used Senge et al.'s (1994) well-known five disciplines describing a learning organization

(systems thinking, personal mastery, team learning, mental models and shared vision), as a starting point, but he added dialogue, by which he meant "intense, high-level, high-quality communications, listening and sharing" (Marquardt, 1996, p. 46). Both Senge et al. (1994) and Marquardt (1996) emphasized the importance of a shared vision as a guide towards common and shared goals of the organization.

In the educational literature, the term learning community has been used to refer to processes and phenomena that resemble learning organizations (Hord, 1997). Studies of school improvement have indicated how schools have benefited by becoming learning communities in order to successfully meet the developmental challenges (Hargreaves, 1999; Harris, 2002b; Hord, 1997; Newmann, King & Youngs, 2000). Several researchers have presented theory-based arguments about the characteristics of school as a learning community: they emphasize the mutual trust and willingness for open communication of the participants who share their knowledge (Harris, 2002b; Mandl, 1999; Senge et al., 1994); teachers' shared values and shared vision, which focuses on student learning (Hord, 1997); and collaborative knowledge-sharing as a tool for continuous growth for both teachers and schools. Knowledge sharing is a fundamental transformation of the teaching profession itself and a route to creating collaborative cultures (Fullan, 2002; Hargreaves, 1999; Hord, 1997). Knowledge sharing is the first developmental step, and it should lead to knowledge creation where teachers use their shared knowledge, based on individual practices and theoretical understanding, to create together more advanced ways of collective working (Hargreaves, 1999). Further, in such schools, the staff has opportunities to influence the school's activities and policies (Harris, 2002b; Newmann et al., 2000), teachers' collaboration is supported, and teachers assume collective responsibility for attaining the goals (Newmann et al., 2000; Scardamalia, 2002).

In Studies III, IV and V, the focus is on both the individual and the community: In study III, on the classroom of the students, in study IV, on the teacher community and on the school, and in study V, on the classroom. In these studies, the theoretical understanding about 'community' was as described above. I like the concept of community of practice (Lave & Wenger, 1990), originating from the socio-cultural discussion: it is a powerful concept to describe the relationship between an individual and a community. I have used it vaguely in Study III in describing how students' formed a group for knowledge-creation goals, in which they had a shared project (= the entity of their various ICT works) and in which the responsibility was shared (see the description of students' communities of practice in Hakkarainen et al., 2004). However, the studies were not analyzed using the theoretical framework of Lave and Wenger.

From technology-related skills to digital competence

Especially for the policy-makers, the development of students' ICT skills has been essential and a means for achieving the information/knowledge society, as described above. The content of the desired ICT skills has been less obvious; it has been defined differently based on the point of view and on the expected needs; moreover, the ICT

skills are complex and time-related, and it is obvious that the content is still emerging. Various terms have been used: *computer skills* were used in the 1980s–1990s when a computer was the main innovation, and it was considered important to learn to use it.³ Later on, *information technology skills* were used to cover also the first Internet-related skills, and it was usual to integrate teaching information technology with other subjects. For example, in the Finnish national strategy for education and research (Ministry of Education, 1995), school was expected to give every girl and boy the skills of information acquiring, managing and communication necessary for the information society and for further studies. Basic information technology skills were also expected to be acquired in school. However, these basic skills were not defined. It was also ordered that information technology was not to be taught as a separate subject but it should form an integrated entity with other subjects. *Information and communication skills* have further widened the concept towards the ability to use the increased number of different communication applications in the Internet; often information management skills are included in the definition.

Now it is typical to speak about *digital skills*; these include the ability to use the wide variety of technology-related tools and applications. Some preliminary definitions for knowledge skills are found already in Andersons and Plomp's draft plan for the SITES research project (as cited in Law et al., 2002); they defined the skills and abilities to manage knowledge and to deal with information in the following way: retrieve and organize knowledge; solve complex problems; collaborate, exchange knowledge, work with experts; communicate, give persuasive presentations; construct knowledge products; integrate and critically evaluate knowledge; and identify and evaluate secondary effects.

The European Commission (see Punie & Cabrera, 2006) has defined digital competence as involving the confident and critical use of Information Society Technology for work, leisure and communication. Digital competence is grounded on basic skills in ICT, i.e. the use of computers to retrieve, assess, store, produce, present and exchange information, and to communicate and participate in collaborative networks via the Internet. However, the adoption of necessary skills and competence to use ICT need to be complemented with the mastering and understanding of ICT.

In the OECD's definitions of the key competencies for a successful life and a well-functioning society, a competency was defined as not only consisting of skills and knowledge, but also involving the ability to meet complex demands in a particular context (The OECD Program Definition and Selection of Competencies, 2005). In the OECD's framework, the competencies are classified in three broad categories: 1) use tools interactively, 2) interact in heterogeneous groups, and 3) act autonomously. Each of these key competencies implies the mobilization of knowledge, cognitive and practical skills, and social and behavioral components including attitudes, emotions, values, and motivations. The first key competence, use tools interactively, is especially

³ In the text I use the term which is used by the authors in the referred sources.

important when thinking about ICT in school. This competence means the ability to use technology interactively, which requires an awareness of new ways in which an individual can use technologies in his/her daily life. An individual should have the ability to make use of the potential of ICT to transfer the way of working, to access information, and to interact with others. A first step is to incorporate technologies into common practices to produce familiarity with the technology. To turn this into a practical definition for school, digital competence should consist of technical ICT skills, but also of other abilities such as knowledge creation skills with technology, and skills for understanding, producing, and evaluating digital contents, as well as skills for using ICT for learning. For students, it is essential to participate in diverse creative processes to gain *doer's knowledge*, which promotes agency and experience of control. Students are not only consumers, they are also producers. The task and demand for the educational system is to ensure that a student has the necessary digital competence when he/she leaves school.

In the Nordic ICT study (Pedersen et al., 2006), digital skills are defined as basic cultural skills in the Nordic countries, like reading and writing, but, as Erstad writes in his article (2006), there are various and contradictory views about the role and content of the digital skills in education. In his book, Erstad widens digital skills to include digital literacy and defines it as “skills, knowledge and attitudes in using digital media to able to master the challenges in the learning society” (as cited in Erstad, 2006). With this definition he links the challenges to the ‘learning society’, which indicates a more active, process-oriented perspective on society than the terms knowledge, information or networked society. Another example of widening the technology-related skills to wider competencies is ISTE’s (International Society for Technology in Education) educational technology standards for students (ISTE, 2007). The main competencies are creativity and innovation; communication and collaboration; research and information fluency; critical thinking, problem solving, and decision making; digital citizenship, and technology operations and concepts. These are all turned into practical activities for various school levels (e.g., for grades 3-5, one concrete activity is “Produce a media-rich digital story about a significant local event based on first-person interview.”).

Teachers’ ICT skills have been less often discussed. An interesting review about necessary ICT competence areas for teachers is presented by Sabaliauskas, Bukantaitė, & Pukelis (2006). They defined seven competencies which are needed to integrate ICT into education: basic ICT competencies (however, not defined), technological ICT competencies, ICT policy competencies, competencies in the ethical area of ICT use, competencies of ICT integration into the teaching subject, competencies of didactical methods based on the use of ICT, and competencies of managing teaching/learning process working with ICT. These competencies are far from the ideas of the technical skills, necessary for teachers. Lakkala and her colleagues (2005) found in their study that technology was not a challenge for teachers, but that they had problems in scaffolding students in open learning environments, which refer to missing competencies in didactic methods and in managing the teaching/learning process. Further, in studies IV and V, teachers’ didactic and management competencies with ICT were investigated and discussed.

3.4. Results from innovative projects

Several innovative projects in different countries have given promising research evidence about possible changes in education with ICT. ‘Innovativeness’ in this study is defined widely; I agree with the definition used in the SITES project (Kozma, 2003a): evidence of significant changes, incorporated use of technology that played a substantial role in the practices, showed evidence of measurable positive student outcomes, and showed evidence in sustainability and transferability – although probably all the papers referred to in this study do not meet exactly every aspect of the definition. Among the projects, there are two extensive research projects, which have special importance for research about school and classroom level practices, namely a study by the Centre for Educational Research and Innovation (OECD/CERI) about ICT as a catalyst in innovative schools (Venezky & Davis, 2001), and case studies in the Second International Technology in Education Study (SITES) research project, in which classroom level innovative practices using technology were investigated (Kozma, 2003a; 2003b). These studies, as well as various more limited case studies indicate several changes in, e.g. pedagogical practices, teachers’ and students’ roles and activities, classroom atmosphere, and also teacher and school communities, with the use of technology. Some of the main results are summarised in the following sections.

Pedagogical practices in classrooms

Some case studies have especially examined the impact of using ICT on the changes in pedagogical practices. *ICT skills* were taught in a context integrated into the curriculum and as part of complex skills such as information handling, collaboration and communication, and were embedded in an authentic context (Kozma, 2003b; Voogt & Pelgrum, 2005). *Learning projects* became student-centered; they were longer, more time-consuming processes, and many of the ICT-based innovations involved multidisciplinary and collaborative projects, such as project-based learning and independent inquiry (Kozma, 2003b; Lowther, Ross, & Morrison, 2003; Ruthven, Hennessy, & Deaney, 2005; Yuen, Fox, & Law, 2004). The proportion of authentic activities increased, and students worked on topics meaningful to them because of the connection to real life and the student’s own experiences (Voogt & Pelgrum, 2005; Yuen et al., 2004). *The teacher’s role* changed from that of primary source of information to one who creates structure and provides advice for students, monitors their progress, assesses their accomplishments, and works as a coach (Condie et al., 2007; Kozma, 2003a, 2003b; Lowther et al., 2003; Yuen et al., 2004). Respectively *the students’ role* changed, they were engaged in general and/or online inquiry, and in productive learning (Yuen et al., 2004), which developed their sense of capability and agency (Ruthven et al., 2005), and collective cognitive responsibility (Lakkala et al., 2007). The nature of the teacher’s role has the strongest impact on the student’s role, and thus for the learning outcomes (Yuen et al., 2004). Further, the learning outcomes were dependent on whether teachers and students engaged in working with ideas and not with tasks and activities, based on the ideas of Scardamalia (2002), on supporting the reflective approach to the learning task and on developing an empowering learning culture (Law, Lee, & Chow, 2002). *Students skills* in ICT, problem solving, information management, collaboration and communication (often called “lifelong

competencies”) develop when ICT is used in a student-centered way (Kozma, 2003a; 2003b; Lowther et al., 2003; Voogt & Pelgrum, 2005). There also arose a need to support students’ information searching and processing skills (Ruthven et al., 2005). *ICT was used* for the existing content or to offer the existing curriculum content in a different way, not in changing the content (Kozma, 2003a; Voogt & Pelgrum, 2005; Zhao & Frank, 2003). The use of the Internet helped to give a much wider coverage of topics and it gave access to authentic sources and materials, which helped to establish a sense of contact between the classroom and the wider world (Ruthven et al., 2005). The computer was more frequently used as a learning tool rather than to deliver instruction (Lowther et al., 2003; Ruthven et al., 2005). *The working atmosphere* became more free than in a traditional classroom without ICT, and the relationship between teacher and students was more open and free, because teachers had fewer rules (Schonfield, 1995); students are motivated to work with computers because the activities were more challenging than ordinary tasks, and the overall learning environment was more meaningful (Goldman, Mayfield-Stewart, Bateman, Pellegrino, & the Cognition and Technology Group, 1998; Lowther et al., 2003). In general, in the most outstanding schools, ICT is starting to have a pervasive impact on learning (Office for Standards in Education ICT in schools, 2004).

School level changes

Those case studies in innovative schools, which concentrated on investigating school-level processes, indicate that the use of ICT may profoundly transform the teaching profession (Granger, Morbey, Lotherington, Owston, & Wideman, 2002; Kozma, 2003a; 2003b; Venezky & Davis, 2001). In analyzing cases in the SITES study about innovative practices, Yuen and his colleagues (2004) identified characteristics of successful schools. These were strong educational vision and experience in innovation and ICT use; strong educational vision and experience in ICT; a reputation for being an innovative school, and alignment with government education policy. Other case studies indicate that schools with intensive ICT usage conducted several community-directed strategies for solving the problems of using ICT, especially transformations of school organization. For instance, at some schools, there was a shift from hierarchical structures to more horizontal ones, and improvements in staff development through building the teachers’ professional community (Venetzky & Davis, 2001). Teachers’ effective professional development requires training in a broad sense, integrating teachers’ ICT competencies with their pedagogical knowledge and skills (Owston, 2003). In their case study, Dexter, Seashore, and Anderson (2002) reported findings that showed that a strong professional teacher community and a well-supported instructional technology were in reciprocal and recursive interaction: teachers’ common need to learn about technology contributed to the development of the professional community, which again contributed to more integrated and focused uses of technology, the refinement of the school’s visions, and the gradual development of a better support system for technology use. The use of ICT inspires teachers’ pedagogical collaboration and functions as a catalyst of change since many educational settings in which ICT is used become cross-disciplinary; they involve large projects and process-oriented activities, and require the special expertise of several teachers. Teachers

become team members instead of independent workers. One of the necessary conditions across the successful schools with ICT was teachers' personal commitment and an appreciative, collaborative community with the support of the principals (Granger et al., 2002; Owston, 2003; Vosniadou & Ioannides, 2004).

3.5. ICT in ordinary school practices

How well are the visions and decisions of technology use fulfilled in the practice of ordinary schools? Several statistical surveys have been conducted on ICT access and use during recent years. In Europe, PISA conducted surveys in 2000 and 2003. The school administrations in Nordic countries together ordered one survey, conducted in 2005. The EU Commission conducted one in 2006, similarly the International Association for the Evaluation of Educational Achievement (IEA) collected data in 2006. The data of the surveys have been gathered somewhat differently and direct comparisons are not valid. However, the general trends are the same. In general, ICT has been adopted into education in western countries during the last five years, although the level of computerisation in schools varies widely from one country to another (Korte & Hüsing, 2007). The increase has been especially rapid in Internet connections, as the results of the PISA surveys from 2000 to 2003 indicate (Programme for International Student Assessment, 2005; see also Korte & Hüsing, 2007). For example, in Finnish schools computers with Internet connections increased from 83.7 % to 92.1 % (Programme for International Student Assessment, 2005).

The ratio of students per computer gives a simple indicator of *the ICT resources in schools* in European countries. In 2003, in ten countries, the ratio was lower than 8, among them Finland. Based on the PISA survey, of pupils aged 15, in ten countries the number of students per computer was more than 10 (Eurydice, 2005). In 2006, on average, 9 students shared a computer, but the differences among 27 European countries are wide: in Denmark, the Netherlands, the United Kingdom and Luxemburg there are 4–5 students per computer, in Latvia, Lithuania, Poland, Portugal and Greece, 17 students share a computer. The Nordic countries, the Netherlands, Estonia and Malta have the highest share of broadband connections, in about 90 % of the schools (Korte & Hüsing, 2007).

The ratio of students per computer tells nothing about the use of computers or the pedagogical contents of the use; it is just a rough estimation of the resources available. In the 2000 PISA survey, in the Nordic countries and in the UK, schools did not differ in their resources (Eurydice, 2004), but the newer studies indicate that there are also school level differences. In a Nordic survey⁴, there was variation among schools; in 17 % of schools there were fewer than four students per computer, in 41 % there were 4–10 students per computer, and in 41 % more than 10 students per computer (Pedersen et al., 2006). In Finland, in about 80 % of schools, there are fewer than 10 students per computer, and in about 20 % of schools, even fewer than 5 students per computer.

⁴ The study was carried out in Nordic schools from elementary school level to upper secondary school level. According to the authors, the results might reflect the situation of more ICT-oriented schools.

(Kankaanranta & Puhakka, 2008). Similar variation exists in all countries that participated in the most recent SITES study. In general, the lowest student-computer ratio was in Canada, Denmark, Hong Kong, Norway and Singapore (Pelgrum, 2008).

There are different estimations about the amount of *computer use* in education, mainly depending on the methodology of the study. The results of the PISA survey (OECD, 2004) of 15-year-old European students showed that frequency of computer use in school varies widely and that this is, naturally, related to the amount of computers in the school (Korte & Hüsing, 2007; OECD, 2004). In Nordic countries and Austria, use of the Internet is particularly frequent (and low in Spain, Italy, Latvia, and Poland). Students use computers for email and browsing the Internet, while the use of educational software appears to be declining (OECD, 2004). According to the most recent data (Korte & Hüsing, 2007), teachers use computers in classroom often, but again, the differences among countries are remarkable. The highest percentage of teachers that use ICT in the classroom are in UK (96) and in Denmark (95), the lowest ones in Latvia (35) and Greece (36). Korte and Hüsing (2007) say that in Europe, among the frontrunners in ICT use in school, the use of ICT has become the norm for most of the teachers and pupils in all aspects of life. They probably overestimate the situation because the intensity of ICT use is not very high, even in these most recent statistics.

For students, the ICT resources at home are most important for access and development of skills; in the Nordic study, eLearning Nordic (Pedersen et al., 2006), the authors even say that there is a digital gap between school and home. In the PISA 2003 survey (Eurydice, 2005) 81 % of students aged 15 said that they have a computer at home, and the use of the computer was routine: 99.3 % of students had used it. Over 50 % said that they use it regularly, mainly for playing games, for looking information on the Internet and for communicating via e-mail or 'chat-rooms'. Although the use is very common, the length of time of using a computer varied widely from one country to another; it was highest in the Nordic countries in which the majority of students had used a computer for over five years. Computerisation seems to be spreading through western countries very rapidly.

The optimistic visions about deep-level changes in educational practices towards desired pedagogical outcomes over the years have not come true as such. A first indicator is the amount of computer use in school, which is still quite low and varies remarkably among countries, as the results of the PISA survey show (reported in Eurydice, 2005). Altogether

13 % of students aged 15 said that they never use computers at school, and the girl/boy differences were significant in many countries, including the Nordic countries. As an example of a newer Finnish study, only 5.7 % of 14-year-old students used ICT

in school quite often or very often; 80 % of them used ICT at home to that extent⁵ (Lahtinen, 2007).

Moreover, technology has not been implemented to transform but to maintain and support the existing practices; according to Cuban (2001), most teachers that use technology tailor the use to fit the familiar practices, not to revolutionize them. Salomon (2002) wrote that the technology used has not affected the educational process and the pedagogical practice of daily life in school to produce outcomes such as independent and deliberate thinkers, lifelong learning skills, and the capacity for solving complex problems alone and in teams, the capacity for adjusting to rapid changes in employment patterns, technology, and required skills. So although ICT is used in classrooms, neither a high level nor innovative pedagogical practices are self-evident (Lehtinen, Sinko, & Hakkarainen, 2001). Empirical studies in ordinary schools and classrooms give evidence supporting the conclusion that there are still several shortcomings in implementing ICT, compared to expectations. A Nordic comparative study (Pedersen et al., 2006), an American multiple case study by Ganesh & Berliner (2005) and a Canadian study among teachers and administrators (Gibson & Oberg, 2004), together with several minor studies, show that ICT is not used to transform teaching methods but to support the teaching of domain content, while the school use of ICT is commonplace and monotonous. Teachers adopt ICT mainly in the existing practices of their subject subculture (John, 2005), supporting their existing teaching practices (Kaisto, Hämäläinen, & Järvelä, 2007). Technology experiences in school have not used the transformative power of educational technology; the experiences had not been especially exciting for students, the drill and practice exercises were the most common type of exercises (Smeets & Mooij, 2001), and students used technology during their leisure time more actively, richly, and more extensively (Ching, Basham, & Fang 2005; Vuorela, 2004). For example, the Internet was used infrequently and it was used mainly for information search without students practicing information organization and analysis (Gibson & Oberg, 2004; Jedeskog & Nissen, 2004), with students being more often consumers than producers, working more often alone than collaboratively (Jedeskog & Nissen, 2004; Pedersen et al., 2006). Students still worked with facts and skills instead of understanding e.g., through collaborative discussion (Jedeskog & Nissen, 2004), and teacher-centered instruction was the norm, even in the computer-based classes (Cuban, 2001).

In Finnish schools the situation is similar, although Kozma (2005) gives a very optimistic future view of Finnish schools. In his study, consisting of nine innovative classroom case studies and a policy analysis, he states that in Finland all educational components, including schools, are organised around goals and visions, and that the overall approach to education change is the knowledge creation approach, by which he means that education focuses on developing the capacity of students, teachers, schools, and communities to create, share, and use new knowledge so that knowledge creation,

⁵ The data were collected in 2005–2007, and they were gathered in a limited area so the results are only indicative.

learning and improvement become continuous, self-sustaining activities. The classrooms investigated were chosen for the study because of their innovativeness⁶, and it is self-evident that these cases were extraordinary. In this sense, Kozma's results do not describe the Finnish situation in general. In Finland, the extent and practices of implementing ICT into education varies, depending on the school. The information society looks different from the ordinary school than it does from an active and innovative pilot school. In the former, even the very basic infrastructure is still insufficient, and there are rather severe differences between schools, e.g. in the ratio of students per computer and in the technical and pedagogical support for ICT, according to a national survey conducted in 2004 (Opetusministeriö, 2005). The number of computers is dependent on the size of the school: in small comprehensive schools (number of students < 31) there were 4.3 students per computer, and in large comprehensive schools (number of students > 400) 8.8 students. Similarly, in small upper secondary schools (number of students < 101) the ratio was 4.1, and in large schools (number of students >1000) 18.2. This also somewhat describes the differences between rural and urban schools because the large schools are located in urban areas. The resources for technical support also vary among schools: 30 % of comprehensive and 6 % of upper secondary schools had no technical support, while 71 % of comprehensive schools and 49 % of upper secondary schools had no pedagogical support for the use of ICT. These few results about the technological infrastructure show that although Finnish schools might, on average, be in a good situation, this is not always the case, and sometimes the level is far from good. Even within one city, the differences in technical infrastructure, and in teachers' skills and use of ICT varied (Lehtinen, Ilomäki, & Hakkarainen, 2003).

Teachers' problems in implementing ICT into educational practices.

Implementation of ICT into the classroom has often been investigated by focusing on a teacher's individual characteristics, such as a teacher's pedagogical conceptions or experienced problems. The second major focus has been on school level: how the school should support teachers' implementation processes. Third, some of the studies have focused on external aspects, such as teachers' in-service training or necessary technical or pedagogical support, as well as the lack of appropriate educational material. These are factors that, e.g. municipal school administration or even commercial publishing houses work with. Only very few studies have focused on the societal level: how the educational system is organised, and how this supports the implementation or the transformation of teaching practices. In the following section some of the main results reported in the earlier studies are described.

Teacher characteristics and the use of ICT

The individual teacher is usually the one who makes the decisions on the classroom practices, also concerning technology. It is obvious that teachers use such tools and

⁶ One of the cases investigated is briefly presented in Study IV, the computer-supported collaboration in Länsimäki School.

practices that support their beliefs about “good learning” and tools that fit easily into the existing conceptual and social organization of classrooms. As Marx, Blumenfeld, Krajcik and Soloway (1998) noticed, the use of technology tools mainly maintains the existing culture, and they have little potential for transforming teachers’ work, or the nature of teaching and learning in classrooms. In the studies of Hakkarainen et al. (2001) and Moseley et al. (1999), it was found that there was a relationship between teachers’ pedagogical conceptions and the type of instructional use of ICT. Teachers who intensively used information technology emphasized the importance of using ICT for facilitating students’ participation in progressive inquiry, collaborative learning, and the learners’ active engagement in the knowledge formation process, but as Lin (2001) says, the relationship between teachers’ conceptions and practice, is complex, not clear or simple.

Teachers with good ICT skills used ICT more, and more often in a student-centered way (Moseley et al., 1999), and they appeared to have adequate pedagogical means for pursuing new pedagogical practices (Hakkarainen et al., 2001). In a study on the instructional use of software (Niederhauser & Stoddart, 2001), the results indicated that teachers who used open-ended software had a strong learner-centred orientation and a weak computer-directed orientation, while teachers who used only skill-based software had the strongest computer-directed and lowest learner-centred orientations. Only very few teachers used open-ended software (but probably there were only a few such available). Lim and Barnes (2002) in their case study described, how a teacher who succeeded in using a digital application had long experience in using ICT in teaching, and he had the necessary attitude, skills and knowledge to identify the cognitive opportunities and limitations of the program, and to plan and organize activities to exploit its opportunities and address its limitations. There are also findings regarding teachers who do not use ICT in teaching. Norton, McRobbie, and Cooper (2000) found that teachers did not use ICT in teaching [mathematics] because of a teacher-centered view of teaching as a transmission / absorption image. Because the non-use was essentially based on such beliefs, teachers did not take any actions to increase their ICT-related expertise or access. Selwyn (1999) wrote about ‘computer identity’ in terms of the subjects and courses teachers teach. These computer identities are shaped by many influencing factors, including an individual’s own personal interests, and crucially his or her identity as a teacher, including his or her identity as a teacher of a particular subject. In some subjects, teachers have a stronger congruence with ICT than in others, and the teaching practices are more closely related to ICT, e.g. music teachers were positive about the potential of new technologies both in performance and composition (John, 2005), while for English teachers computers were a natural tool for student writing activities (Zhao & Frank, 2003). In general, probably for the time being, for a teacher identity it is not yet necessary to have a strong ICT competence and to use ICT, although ICT has spread widely to schools.

Teachers differ in their age and gender, both of which are essential factors behind ICT use. We compared teachers of different age groups and genders (Ilomäki, Tapola, Hakkarainen, Koivisto, Lakkala, & Lehtinen, 2001), and the results showed a general trend: male teachers of all age groups (20–35, 36–47, 48–62) estimated their skills

higher than female teachers of the same age. They also used ICT more, both in school and during leisure time. The youngest group of female teachers was at about the same level as the middle group of male teachers. In the comparison between the results of the two years, the youngest and the middle groups of female teachers had increased their self-evaluated ICT use, and the oldest female teacher group had increased its pedagogical use of ICT, although they still used it less than other teachers. So is it then possible to speak about 'teachers' as an entity? Probably not, at least we should keep in mind the generation differences even within teachers. Comparing our clustering with a summary by Reeves (2008), the teacher represents (roughly) the generations as follows: Baby boomers (born about 1943–1960..1964), and Generation X (1961..1965–1975..80). Reeves reminds us that there are generational differences that are worth taking into consideration in the “knowledge worker” [as teachers and students are]. However, this issue is seldom reported in the studies concerning ICT use.

In-service training as a means to support ICT skills

In-service training is one of the (few) ways in which teachers typically have been given support to achieve ICT skills, and it has been successful in a way: teachers, like other people, use ICT in their activities outside school. It is remarkable that this use does not transform to teaching, although it does transform teachers' professional activities such as preparing lessons or administration. The teacher's professional knowledge is situated in practice, in classroom events and activities. It is challenging to change or to develop this knowledge, because new knowledge cannot be learned independently of the situation in which it will be used. Training given outside the school is the usual way of organizing teacher training, especially in ICT. Such learning experiences outside the classroom have been shown, however, to be too far removed from the day-to-day work of teaching to have a meaningful impact. The pressure to maintain the existing classroom environment and the culture is too strong (Karagiorgi & Charalambous, 2006; Marx et al., 1998; Putnam & Borko, 2000). In a study concerning teachers' ICT training (conducted in the UK; Galanouli, Murphy, & Gardner, 2004), the results were somewhat negative. The main critical issues were lack of time given to training, and the exploitation of teachers' own time and expense, as well as the lack of technical and social support, and good equipment and resources. What was generally much more effective was ICT training that was provided by the school itself (Office for Standards in Education ICT in schools, 2004). Technical skills may be sufficient for ordinary classroom practices with pupils and for home use, but many teachers may still lack the confidence to make the best use of the new technical resources (Condie et al., 2007). In a Nordic survey, two third of the teachers in the study had participated in ICT training during the previous three years. However, only one third of the teachers trust in their skills, and they have not noticed that the training would have had an effect on the use of ICT in the classroom (Pedersen et al., 2006). According to Putnam and Borko (2000), a combination of approaches, situated in a variety of contexts, most effectively fosters changes in teachers' thinking and practices. Teacher training typically concentrates on the explicit knowledge about ICT and its use in teaching, while teachers lack understanding and competence about *how to really do it in the classroom*.

Structural practices prevent collaborative development

At best, in several pilot schools, ICT has helped to create teacher collaboration and further, a teacher community that solves the obstacles of using ICT in new and innovative ways. In ordinary schools this is more difficult because they have less support for the implementation processes at the school level. Implementation of ICT sometimes even causes negative consequences for the teachers' community, because of the problems in handling the necessary change and the need to change the role of the teacher (Erstad, 2007; Ilomäki & Lakkala, 2007). Teachers have several practical problems, which, in fact, have their basis in deep-level structures of the educational system, and the problems are related to the way the teacher's work is organised, e.g. teachers have not enough time to prepare lessons during which they use computers, or to schedule enough computer time (Gibson & Oberg, 2004; OECD, 2004). In a study about virtual inquiry learning, the structural restrictions were the requirements of the curriculum plan, the division of the subjects to be taught, and the difficulties in changing the assessment practices (Lakkala et al., 2007). The conclusions of this study are similar to those in a SITES study (Voogt & Pelgrum, 2005), where they suggest, referring to technology assessments, that there might be a potential gap between the intended and the implemented and attained curricula.

Teachers' networking and pedagogical collaboration within their teacher community are still inadequate, and based on a few individuals (Kaisto et al., 2007). Several investigators have proposed that sharing and creating professional knowledge among teachers at schools is difficult because of certain in-built constraints and obstacles. An engagement in knowledge sharing is difficult in part because of the socio-spatial structures of working that are based on autonomous classrooms in which each teacher is working as an isolated practitioner (Engeström, Engeström, & Suntio, 2000; Fullan, 2001a), and the pedagogical infrastructures make it difficult for teachers to organize innovative learning processes with ICT (Lakkala et al., 2005). Consequently, teachers have very little time during their school day to get together to share ideas and refine their teaching. Teachers are not fully aware of their professional knowledge resources, and they do not deliberately exploit the pedagogical know-how accumulated among themselves (Hargreaves, 1999). There are also normative reasons for the fact that teachers are not in the habit of giving and receiving information; indeed, in many cases, the cultures of schools discourage such knowledge sharing (Fullan, 2001a).

In summary, after 20 years' active implementation and development work, ICT is still a somewhat rare tool for everyday work in classrooms, although teachers and students use ICT widely outside teaching and learning practices. Several successful pilot cases and pioneering teachers and schools are exceptions. The pilot cases are often based on exceptionally good resources, high-level research support, pedagogical and technical training, as well as outside support for the participating teachers, while the contradiction between well-supported and guided pilot experiments in a few schools and the large majority of teachers and schools still remains (Condie et al., 2007; Lehtinen et al., 2001; Office for Standards in Education ICT in schools, 2004).

Thus, the experiences and results are only seldom easily applicable to scale up the teaching practices with ICT in ordinary schools and classrooms. The activities for promoting ICT in education have concentrated on the support within the existing educational system, and the aims to support the ‘knowledge society’ have not spread to the basis of the educational system. The curriculum structure is still based on the division according to the domains of science, although the integration of ICT into all domains is an improvement. The teacher’s professional position and, e.g. salary are still based on the number of lessons she/he teaches, while additional work is minimally compensated, joint teacher projects have to be (mainly) planned and organized after lessons (without any extra payment), like most in-service training which is usually limited to a few-days’ course during one year. In addition, there is not enough extra technical staff in schools to take on the burden of maintaining the technological infrastructure. Moreover, structural conditions limit the changes; e.g. lessons usually last 45 minutes, the domains of subjects mainly change after each lesson (in secondary school), and one teacher is alone responsible for one class. Schools have very little extra funding for buying material, for organizing study trips or for inviting visiting experts to teach occasionally. In summary, the new technology is mainly implemented within the existing traditional educational structures, practices and curriculum.

Characteristic of students’ ICT skills

The present-day students⁷ are essentially in a different situation from previous generations, with the large majority of students having ICT skills that are of a different type from their teachers’ (and parents’), often better and wider; even the time spent using a computer efficiently supports the improvement of ICT skills. It is obvious that for the younger generation using ICT is easy and ordinary, characterizing a life-style consisting of the functions of both working and learning, as well as functions of leisure time, like gaming or uploading and listening to music. Nardi and O’Day (1999) call this phenomenon ‘information ecology’, by which they mean a system of people, practices, values and technology in a certain environment. In such an “ecosystem”, technology is not in the centre but it is integrated into the existing practices and manners, and users and tools form a wide variety, complementing each other.

There is a cultural gap between students and teachers in terms of the digital world, and, as mentioned in Pedersen et al. (2006), very few teachers know what is going on in the digital world of a 13-year-old student (see also Ilomäki & Rahikainen, 2001). This differentiation and students’ ICT competence are challenges for teachers because the digital skills are nowadays basic skills, such as reading and writing (Pedersen et al., 2006). Digital skills divide into very different sub-skills of which only some are important and used in school. As presented above, students’ informal learning of ICT and experiences in using ICT are far more attractive than the school can typically offer. As a result, students face few challenges in using ICT in school. Moreover, there is probably in every school a group of students with high-level expertise in ICT. These

⁷ By ‘students’ researchers usually refer to teenagers or older youth. In the sub-studies of this dissertation thesis, ‘students’ were 13-18 years old; the mean was about 15.

“student-experts” have the kind of adaptive expertise which is useful in novel situations with technology: they learn quickly in practice, they have networks to help and give guidance, they are committed, and they are not afraid to face challenges. Only seldom can these students gain from the ICT use in school, although they could be an important source of help and support at school level.

We do not need to over-romanticize the younger generations’ ICT competence but it should certainly have an effect on classroom practices and on the teacher’s role, and as such, it is a challenge to teachers; in general, a challenge that is not met, as e.g. when Erstad (2007) describes the different strategies that teachers used when facing students’ better ICT competence. Some teachers competed with students, to some it was a challenge for their didactic and subject-oriented skills, while others teachers simply ignored computers. Especially Internet services challenge previous practices of working and learning. Weller (2007) suggests that the essence of the Internet is in robust, decentralized, and open communication; these technological features have also become social features and influenced the social values of the net. Many virtual communities have adopted these, but, as Weller says, these elements do not characterize learning communities, not even e-learning communities. Yet, the new generation of learners will become used (and some of them already are) to these features and they demand them also in the learning communities. The challenge is how to integrate the technological possibilities, the sophisticated communication strategies of the learners used to the Internet, and the formal structures of learning organizations.

There are some characteristics in students’ ICT skills which are essential when thinking about the use in school. Students’ ICT skills are often learned in informal learning contexts, at home and with friends; this concerns boys especially (reported in several studies, see e.g. Eurydice, 2005). In their study, Ruthven et al., (2005) say that sometimes this informal learning means insufficient or odd ways of working, and that especially the information-processing skills need support: students’ searching procedures are inefficient and they need more systematic guidance to develop these. Similar findings were reported, for example, in a study on sixth grade children studying science (Wallace, Kupperman, Krajcik, & Soloway, 2000): students were not very effective in finding useful information (but students were well engaged and involved in the inquiry and search activities). In another study on literacy skills of sixth grade children (Bowler, Largeb, & Rejskindc, 2001), the researchers found that fact-finding skills were inadequate, and efficient use of the web implied a background of knowledge about computers and inquiry. Students did not understand their role as knowledge makers and the need for responsible use of information. As the authors say, understanding that one must back up statements and opinions with reliable proof should be seen as a life skill, but such understanding was missing. They emphasized further that the needs and abilities of grade-six students do not match the design of the Web. As a matter of fact, information searching in the Internet is not easy for older students, either, as studies among upper secondary school students and experienced adult graduate student Internet users showed (Kiili, Laurinen & Marttinen, 2008–2009; Nachmias & Gilad, 2002). Most of the upper secondary school students only seldom evaluated the credibility of information, and the evaluation of relevance was more

important than the evaluation of credibility. Some students did not find relevant and correct information, although teachers were not aware of this and they trusted the students' information skills too much (Kiili, Laurinen & Marttinen, 2008–2009). Similarly, the search processes of adults were ineffective and often unsuccessful (Nachmias & Gilad, 2002). Lallimo, Lakkala and Paavola (2004) present in their review⁸ that the starting point for effective information-seeking with technological support is embedded in a sound theoretical understanding of the information seeking process, as it is intertwined with meaningful pedagogical practices. The authors put the question whether ICT presents totally new challenges for students' information-seeking skills, or is it more a question of supporting students' basic information-seeking skills regardless of the technology.

The difference between boys' and girls' skills is reported in several studies. The following examples are from the PISA 2003 survey (Eurydice, 2005). The majority of students, of both genders, had the skills for performing simple activities, such as using a file and communicating via the Internet. Although the majority of students also managed more complex file management activities, girls more often had problems, and, further, girls had fewer skills in “complex communication” (e.g. attaching a file to an e-mail message) and advanced applications (e.g. constructing a web-page or creating a programme). There are, however, some results that show that the difference between boys and girls in ICT use and competence is diminishing, e.g. Lahtinen (2007) argues for this in his study of 14-year-old Finnish students. Anyway, the difference between boys and girls is not simple and straightforward, and it is changing rapidly because of the extensive use of the Internet.

3.6. The role and relevance of technology tools

ICT in school has taken several forms during the years it has been used. Technology inventions did not appear out of blue into school; all technology is a continuum of the previous experiments and experiences of technology, stimulated by socioeconomic and cultural factors (Basalla, 1987). Computers were used elsewhere in society and these practices were also introduced into educational applications. The existing pedagogical paradigm and conceptions then formed the structure and the practices of using these applications. Over the years, a wide variety of applications has been invented but only few of them have remained in large-scale use which is very typical for all technology-related innovations (Rogers, 1995).

According to Reiser (2001), two major tracks arose in educational technology at the beginning of major ICT use in education, from the 1980s on: computer-supported learning (also referred to as computer-aided learning and computer-based training) and the use of computer as a tool. The former consisted of different kinds of educational software, which still has a strong representation in learning objects (LOs). For instance, the Nordic countries collaborated in developing, designing and producing educational

⁸ The reviews were evidence-based “answers” to authentic questions of practitioners. This reviewing process was part of ERNIST, a project of the European School Net.

software during the years 1986-1995. (Today collaboration around learning objects is supported, e.g. at European level by the European Commission, in such projects as Celebrate, 2006, and Calibrate, 2008.) Computers as tools were the other important track, and the most popular application was word processing. Some educational tools were also introduced, as well as the programming language Logo. This track, computer-as-a tool, is still alive, and the improved usability of various software has helped to bring the same digital applications into education as elsewhere in the society. In this study, Study IV represents a wide variety of ICT use because teachers of the school used ICT applications in multiple ways. Study V concentrates on the use of learning objects.

Beginning from the 1990s, the Internet revolutionarily changed the supply of technology, also in education. The Internet offered a tool for delivering learning material (e.g. learning objects), an environment for discussions and for publishing, it offered better e-mail applications, and it is a huge information source for searching. The Internet has profoundly changed many ordinary working and social practices. However, the changes in education are still not at a very deep level, as discussed above.

It is striking how much hype new technological inventions always arouse. The adoption of ICT was regarded an important even for national economies, but also other applications have been regarded as the tools to profoundly improve learning. The latest hype was around learning objects, as e.g. Jaakkola and Nurmi (in press) and Parrish (2004) describe. Typically, all these expectations have less support in the field, among teachers. However, with time, the overestimated expectations have come true but on a much lower level.

'Affordance' is a useful concept to explain what and why some technology is adopted. Gibson (1979) defined affordance as something that an environment offers or provides; properties that the user perceives. Thus, the properties are both objective and subjective; they have a reference to the observer but they are not properties of the experiences of the observer. He/she pays attention to the affordance according to his/her needs, but the affordance is always there to be perceived, it does not change. Gibson's concept was essentially naturalistic, based on ecological properties, but it is adopted also for describing less nature- and real life -related entities, e.g. digital tools for learning, in pursuance of expanding and or re-defining the concept (see, e.g. John & Sutherland, 2005; Turner, 2005). John and Sutherland summarize the use of 'affordance' into three different approaches: affordances are about effectiveness, about perception, and about cognitive constructs. In his interesting review about 'affordance' as a concept, Turner concludes by making a distinction in the concept based on the perspective: "from a holistic or phenomenological perspective, affordance, use and context are one. From a design perspective, affordance is not an intangible, elusive property of interactive systems, it might better be thought of as a boundary object between 'use' and 'design for use'" (2005, p. 29).

The concept 'affordance' helps us to understand the functional differences of various learning technologies and the process of choosing these in a more natural and user-

friendly way than, e.g. a list of ICT applications. Conole and Dyke (2004) further develop the idea of affordances of ICT in order to be effectively used in supporting learning and teaching; they created a taxonomy which consists of the following affordances: accessibility; speed of change; diversity; communication and collaboration; reflection; multimodal and non-linear, risk, fragility and uncertainty; immediacy, monopolization; and surveillance. It is obvious that many of the affordances Conole and Dyke list are difficult to adopt in ordinary teaching practices because sometimes these affordances even lead a new problems for the educators and students, e.g. 'accessibility' changes the need from searching to selecting, and 'speed of change' demands deep-level understanding about the phenomena. Obviously, we should consider these affordances against the true needs of teachers since ICT is not only a new tool but also a useless tool for some existing practices. A teacher has first to find a need for ICT because of pedagogical changes, and then ICT can be adopted in teaching practices.

During the years of using ICT in education, the selection of technology, meaning *what* to adopt from the huge diversity of applications, has been a process which determines *how* the pedagogical practices are shaped. The implementation of technology into education is an innovation process. Miettinen, Lehenkari, Hasu, & Hyvönen (1999) regard this as *co-evolution*, a reciprocal interaction among a social network of actors, a technological solution, economic markets and development of learning. We can say that in ordinary schools this co-evolution has not been successful; it has not been reciprocal nor interactive.

3.7. The problematic school change⁹

The implementation of ICT was thought to bring about some changes in education and school, as presented in section 3.1. We know that changes in teaching and working practices in school are often long-term processes. Initiating and establishing a sustainable change in school, the use of ICT like any other change, is a difficult task, because, as Cuban et al., (2001) say, established practices are taken for granted and they are seldom questioned by policy makers, practitioners, researchers, or taxpayers. Although there were ideas, beliefs and expectations about the nature of this change, it was as if the change process itself was only a minor concern. The connection to any existing school change research and discussion was unfamiliar, especially among policy-makers, at different levels in administration. Compared to Mäkinen's (2006) list of primary lessons and principles about change, the implementation of ICT has often been of unhistorical nature, and the difficulty of change has been underestimated. Fullan (2001b) describes change as a three-stage process: first, there is *initiation*, which leads the process, and includes the decision to initiate or adopt the innovative pedagogical practices. The second stage is *implementation*, the process of putting the innovation into practice. Third, *continuation* is the stage in which the innovative practice establishes itself as part of the

⁹ There is a large body of research about school change, but I will discuss here only those issues that are related to changes connected with technology. However, I will use some of the ideas and conclusions Mäkinen (2006) presented in his dissertation. I was inspired by how he summarised the discussion around change in educational institutions.

regular practice within the classroom or the school. In initiating ICT into school, the process has often been limited; it has not taken into account, for example, these three stages. In fact, it was a general expectation that computers would bring about a change all on their own, especially during the first years of the major interest in using ICT in education. Several theoretical and empirical researchers have emphasized, however, that ICT improves nothing per se but it is the pedagogical approach and the way in which it is used that make the difference (Dexter, Anderson, & Becker, 1999; Lehtinen et al., 2001; Salomon, 2002; Venetzky & Davis, 2001; Windschitl & Sahl, 2002). Thus although ICT was and is regarded as important for school and there has been and still is a strong political commitment to it, as described in chapter 3, no strategies and practical activities have existed for a sustainable change in every school, or even in the majority of schools. The policy discussion has been on a general level, and the practical implementation of ICT has been based on a few particular aspects, which have been regarded as key elements, such as improvement of technical resources or (technical) teacher training. When comparing the ICT implementation to Mäkinen's (2006, p. 48) list of primary lessons and principles of change, it is obvious that there has been a lack of a "deep understanding of the structures, processes and cultures of the educational institution in question, and of the larger socioeconomic and political arena in which it exists" so that the change should and could be achieved systematically. This has consequences in practice: for example, Fullan (2001a) writes that the lack of investment in knowledge sharing and creation makes the attempts to share and use new knowledge enormously difficult. ICT implementation is often, and especially on a large scale, separated from the "traditional" school improvement activities, while the process has been mainly technology-driven. This emphasis on technology is understandable at the beginning of the implementation process: school administrators did not have the kind of expertise that was needed for implementing computers and networks into school. The solution was often to set up special technology expert teams to conduct the implementation process.

In ordinary schools, ICT implementation has often been a top-down process, in which schools or teachers cannot control or influence the events in any significant way. The pressure to use ICT in teaching practices has been strongly characterized as coming from outside the school, as well as in the case of the implementation practices (Pouts-Lajus, 2004). This is contrary to the research findings that for effective adoption and successful use of ICT a holistic approach is needed, and that in the change process the most effective way is to have an inside process, with school as the centre of change and teachers as an intrinsic part of the change process. Harris (2002b) emphasized the centrality of teaching and learning in the pursuit of sustained school improvement. In the UK, the results indicated that schools in which ICT was successfully implemented, had a well thought-out approach to engaging pupils as learners (Office for Standards in Education ICT in schools, 2004). Only after fundamental issues of pedagogy and learning were identified was the place of ICT identified and established. Similarly, Erstad's (2007) results from Norwegian schools show that schools working systematically in different areas, with an organizational framework, flexible methods and focus on learning, succeeded best in the educational use of ICT. Similarly, Mäkinen (2006) points out that in the change process, the importance of reflecting not only on the means but also the ends in educational institutions learning outcomes.

Many empirical studies examine the role of teachers in adopting ICT in school. Teachers are essential for a successful change process; they are the agents of change and the main catalyst for change, as Dexter et al. (1999) emphasize. Teachers need to be committed to the change process, which will involve them in examining and changing their own practice (Harris, 2002b, see also Newmann et al., 2000). Teachers' collaboration is important (Erstad, 2007), as it provides mutual support, as well as support to elaborate common agreements and practices concerning how and when to use computers, and to set shared goals for ICT usage (Granger et al., 2002; Vosniadou & Ioannides, 2004). The teacher community should take part in deciding and designing the practical implementation of ICT, e.g. where the computers are located, for what purposes students are allowed to use them, or how the ICT-related pedagogical and technical support is organized. In a successful ICT implementation, the principal and the school board are also key actors (Erstad, 2007; Nachmias, Mioduser, Cohen, Tubin, & Forkosh-Baruch, 2004), Nachmias et al. also emphasize the ICT coordinator's role. Problems of ICT implementation are likely to emerge, if the computers are located in computer labs, if the teachers have low expertise in ICT, if there is a lack of teacher cooperation, and if the ICT coordinator does not have clearly specified duties and status (Vosniadou & Ioannides, 2004).

We can with good reasons ask whether ICT implementation is a change at all, and, further, what is *change*, and what is *progress*? Different paradigms explain the school change (in terms of ICT) differently, sometimes even contradictorily. Mäkinen (2006) calls these explanations "sociological beliefs", influencing how we see educational institutions, the relationship between them and society, and the role of teachers interacting with these social structures. Rasmussen and Ludvigsen (2007) compare Larry Cuban's and Yrjö Engeström's approaches to explain the educational change process connected with ICT: they mention Larry Cuban as a researcher who investigates one phenomenon [ICT] over others, in a focused way. Yrjö Engeström's version of the socio-cultural activity theory represents for the authors a multi-levelled approach, which they regard as a better tool to analyse the change in terms of ICT. Both these two can be used; Cuban's approach has been the major paradigm, both in research and in practical ICT implementation. This is understandable as ICT has been a major [new] factor in society, at all levels and in almost all areas. In education, this meant, unfortunately, the emphasis of technology over pedagogy. Now that ICT is common and accepted, a wider approach should be used, considering the phenomena from several perspectives and in terms of various factors with ICT as only one of the influential elements.

Cuban et al. (2001) suggest two different explanations for the transforming educational practices associated with ICT: the "slow revolution" [which seems to represent progress], in which small changes accumulate over time and create a slow-motion transformation. This explanation is anchored in the notion of lag-time between the invention of a new technology, the adoption of innovations and the slow spread of its virtues through the general population. According to this explanation, the adoption of technology is an inevitable result which will come about anyway. The second explanation tries to account for the sustaining of teacher-centred practices. The use of

technology has continued routine instructional practices because of the contextual factors rather than individual factors. According to this explanation, history and context are essential factors, embedded and complex. To obtain transformation through technology, we should concentrate on major changes, such as how schools are organized, how time is allocated, and how teachers are prepared.

4. RESEARCH QUESTIONS AND METHODS USED IN STUDIES

4.1. The context of the studies

All sub-studies of this dissertation have been carried out in the context of ICT-related research and development projects. Study I was conducted in the context of the Educational Technology Project of the City of Helsinki (reported, e.g. in Ilomäki & Lakkala, 2003). The original data were gathered for policy-oriented evaluation research to be used in municipal decision making. In Study II, the data gathered for the Educational Technology Project of the City of Helsinki were compared with later data from a similar policy-oriented project in the City of Espoo (The Espoo ICT Development Programme 2000–2004). Studies III and IV were carried out in Länsimäki School. Study III was conducted in the context of the portable computer project (reported, e.g. in Sinko & Lehtinen, 1999). Study IV was conducted in the context of three research and development projects: the portable computer project, a computer-supported collaborative learning research project (Van der Meijden, Simons, & De Jong, 2000) and an OECD/CERI study (reported, e.g. in Venezky & Davis, 2001). Study V was conducted in the context of the Celebrate project (Context eLearning with Broadband Technologies, 2006) during 2002–2004, sponsored by the European Commission. The goal of this project was to create, use, test and investigate learning objects.

The context of and the connection to practice-oriented development projects have both advantages and disadvantages. The authentic context and the customers' interest in the results have motivated the research; it has a connection with real-life practices and it concerns novel and essential questions for the community. The research was appreciated and regarded as an important part of the project. However, research is more time-and-effort-consuming than the customers of the studies have sometimes understood; their need is for rapid applicable results and suggestions, and recommendations based on empirical data, rather than scientific aims. The interest of the customers lies in different questions than those of the researchers, while the dependency on external funding may direct the research aims and questions (as Cheek, 2005, writes about funded qualitative research). Among policy-makers, there might even be pressure to achieve results that justify the activities conducted; recently, especially the strong commitment to and heavy investments in educational information technologies, as noted by Selwyn (2002) writing about the policy in the UK: educational research should 'prove once and for all' the cognitive benefits of IT use for the learner.

As a solution to these somewhat contradictory needs and goals, the practical research work was of two kinds, based on the use and dissemination of the results: the evaluation results of the development projects have been reported for the customers in several reports, national conference papers and presentations as well as in joint meetings of the decision-makers and researchers. In addition, some of the results of the projects have also been reported in scientific forums, in conferences and journals.

4.2. The emergence of research questions

The sub-studies were conducted in ordinary schools: the Länsimäki School studies (Studies III and IV) were the first to be started. The research questions were formed during the years of various projects, in close connection with teachers and students, and through observing daily activities and experiences in the school. When the research and development process of implementing ICT in Länsimäki School began, the situation was new and open for the researcher, and because of this, the aims were general: to discover what kinds of experiences students would have with the laptops in school use, and how this use would have an effect on teaching and learning. The researcher had some vague and preliminary ideas about the research aims, but the basic solution was to follow an ethnographic approach and gather all possible data to find out what would be interesting for further investigation. Later on, the more precise research questions were constructed in an iterative process in which the phases of theory building and considering the empirical data took turns. The approach was similar to so-called abductive methodology (originally presented by C. S. Peirce): discovering reality by means of clues and signs, which act as starting points (Bertilson, 1996). Hypotheses were sought to explain any surprising or curious phenomena, and the construction of theories was based on these explanations (Hanson, 1961; Paavola, 2006). By linking together sets of observations with conceptual patterns of explanation we "see" reality (Bertilson, 1996). A "surprising anomaly" (see Hanson, 1961), e.g. in study III was the observation that *some students*, already at the end of the first year at lower secondary school, *were paid for some ICT tasks*. For whom did they work? How did someone find these students? What kinds of tasks were they paid for? Why was the work worth paying for? Similarly, in Study IV, there was a curious finding at the end of the first year of the laptop project: although it was made as easy as possible to join the group and teachers were given several advantages compared to teachers in other schools, *some teachers stayed out of the project*. Why? Why were others very motivated and interested in ICT? Another finding was the role of technology: *sometimes it caused more problems than advantages and it did not transform any teaching and learning practices as such*. A hypothetic-deductive model was could not be used in these studies: it was obvious that testing a few hypotheses would not explain the phenomena well enough in such an ill-defined and changing context; there was a need for methods that would reveal the essence of the phenomena better than testing hypotheses. The development of the research ideas was based on the collective processes with teachers, the principal, and members of the research group; the ideas were discussed and compared together, and then the researcher formed these into research questions.

The research questions of the quantitative Study I were based on data and findings of national evaluation studies (Hakkarainen et al. 2000; 2001; Ilomäki & Rahikainen, 2001), which were conducted immediately after the first three-year process in Länsimäki school, and which were affected by that experience. The research questions of the quantitative Study II were based on the previous data analyses of the statistical data from teacher and student questionnaires in Study I. The data analyses produced the idea of merging the data of these two questionnaires and comparing the results with

similar data gathered in Espoo two years later. The basic question behind this was how teachers and students as representatives of different generations, as well as the genders, differ in their skills and usage of ICT. The research questions in Study III emerged during an intensive three-year observation period. The research questions of Study IV emerged from the findings of the practical, as well as scientific, research projects during several years in the same school. The three different projects produced data which fitted well with the questions about school and teacher community development. In Study V, the theories of learning and knowledge practices¹⁰ were intertwined with the observations of the cases, and the research questions then emerged from the combination of these two.

These general issues of interest were constructed into three major goals, which then were investigated in the sub-studies as follows:

1) ICT-related goals:

How have the ICT competence and use of students and teachers developed? Do students and teachers differ in the relation to these? These were investigated in Studies I, II and III.

2) Community-related goals:

How do a teacher community and teachers as individuals adopt ICT as a pedagogical tool? What kind of effects does ICT have on school community development.

This was investigated in Study IV; also implicitly in Study V.

3) Learning environment and teaching practices -related goals:

What consequences does the intensive use of ICT have for the learning environment related to technology? How does the implementation of ICT influence teaching practices. These were investigated in Studies IV and V.

The longitudinal construction of research questions, data processing and theory construction in the sub-studies followed the ideas of abductive methodology (Paavola, 2006), and the design of the dissertation study represents an “open” approach: it consists of a series of smaller investigations, each one building on the results of the previous studies, which have then been integrated into a whole (Strauss & Corbin, 1998).

¹⁰ By knowledge practices I refer to a new concept, defined as “An innovative process, routine, or procedure of working with knowledge. Knowledge practices represent socially constituted, rather than merely individual activities. Individual agents may, however, develop innovative practices of their own through networking connections with expert communities.” (Knowledge Practices Laboratory, 2006.)

4.3. Mixed method solution

As presented in several methodological works, quantitative and qualitative research methods have evolved from different kinds of paradigms, and they differ in their epistemological and ontological backgrounds, which, of course, have implications for the studies, their aims and results, and moreover, for the interpretations of the results (Brannen, 1992; Flinck; 2002; Guban & Lincoln, 2005). The researchers representing quantitative or qualitative methods have competed especially in the social sciences but also in other disciplines (as presented, e.g. by Johnson and Onwuegbuzie, 2004).

Is it then, even in principle, possible to mix methods which have their basis in various theoretical backgrounds? Some of the so-called purists regard it as impossible (Johnson & Onwuegbuzie, 2004), e.g. Ratner (1997, p.87) as a qualitative cultural psychologist warns that: "Eclectic mixing combines antithetical principles in an incongruous fashion. It preserves the flaws in positivism and allows them to weaken rather than strengthen qualitative methodology." On the other hand, there have for a long time been researchers who see the dichotomy setting as too simple and absolute (e.g. Ercikan & Roth, 2006; Hammersley, 1992; Salomon, 1991) because, as Ercikan and Roth say, natural and cultural phenomena in general are simultaneously quantitative and qualitative, and as Salomon writes, the different paradigms face similar challenges and demands, although they respond to these in different ways. The "paradigm war" is nowadays less obvious, although it still exists, as Maxwell (2004) has found concerning American scientific discussion in education, and Hodginson (2004) concerning the British discussion. There is, however, a strong and growing group of researchers who believe in the third paradigm, the mixed methods research¹¹, and who believe that to combine the methods produces better research, e.g. Teddle and Tashakkori (2003) expect that the mixed methods research will in the future be firmly established alongside the other two paradigms. Promising development work is, indeed, going on, and e.g. mixed methods research has been structured in various ways, while procedures for conducting mixed method research have been created (see, e.g., Teddle & Tashakkori, 2003; Creswell & Plano Clark, 2007.)

There are various trends of mixed methods (Teddle & Tashakkori, 2003). One definition of mixed methods research is that it is "the class of research where the researcher mixes or combines quantitative and qualitative research techniques, methods, approaches, concepts or language into a single study" (Johnson & Onwuegbuzie, 2004, p. 17). In the recent literature, the definition is widened to a multiple set of studies (see, e.g., Creswell & Plano Clark, 2007); they also add to this definition that "Its [mixed methods research] central premise is that the use of quantitative and qualitative approaches in combination provides a better understanding of research problems than either approach alone." (p. 5.) In this dissertation study, the underlying belief is that mixed methods research intentionally engages a multiple set of approaches; all approaches are valuable and have something to contribute to

¹¹ 'Mixed methods research' is the most frequently used name for the methodology (Creswell & Plano Clark, 2007).

understanding, but only partially. The use of several approaches and methods leads to a better understanding of the objects of investigation. Further, the paradigms are social constructions, historically and culturally embedded discourse practices, and objects for changes (Greene & Caracelli, 2003). Holding on to only one approach and one method does not make room for the development of research.

In this study, mixed methods were chosen because of the complexity of the research object; it was necessary to investigate school from various perspectives over a longer period and to use several kinds of research questions to obtain a general view and as full a picture as possible (similarly as Salomon, 1991, writes about using various methods in school research). Mixing various methods allows the possibility of getting a more accurate picture about what is going on, while different methods help to answer slightly different questions (Todd, Nerlich, & McKeown, 2004); they give an opportunity to present a greater diversity of views (Teddle & Tashakkori, 2003) and help us to understand complex phenomena (Newman, Ridenour, Newman, & DeMarco Jr., 2003). The actual research process of this dissertation study emerged as an interplay between qualitative and quantitative methods; the design of the study developed during the research process (Strauss & Corbin, 1998). The study represents the exploratory design of mixed methods research (based on the structuring of Creswell and Plano Clark, 2007); qualitative results helped to inform and develop quantitative methods. It was necessary and meaningful to have an iterative research process, in which the methods, as well as the research questions, evolved on the basis of the previous studies and experiences (as, e.g. Johnson and Onwuegbuzie, 2004, and Todd et al., 2004, present the reasons for combining various methods). Finally, one more reason for using mixed methods was practical: the researcher is a member of a research team, in which the understanding of the methods is wider than that of an individual researcher. It was an easy and natural way of research collaboration to combine methods and share colleagues' expertise. This also helped to overcome one of the problems of mixed methods: the need for a wide understanding of various methods (Creswell & Plano Clark, 2007).

Creswell and Plano Clark (2007) present various ways of using mixed methods. One of these is an overall combination of individual studies. This is how this study is constructed. The sub-studies form a mixed methods research by representing different methodologies themselves. Two of the sub-studies are also carried out with this approach; an embedded mixed methods procedure by Creswell and Plano Clark (2007). The sub-studies represent the various paradigms as follows: quantitative: Studies I and II; qualitative: Study V, and mixed methods: Studies III and IV.

The mixed methods approach also has problems. First of all, a strict distinction between quantitative and qualitative paradigms is the main problem. Is it at all possible to combine various data and if it is, how should this be done? Ercikan and Roth (2006), among others, have discussed the nature of data, and they show how phenomena are both quantitative and qualitative. Second, the mixed methods research is still emerging, and the exact procedures and techniques of collecting data and merging them are not yet established; there is still an undefined "grey area" of studies (Creswell & Plano

Clark, 2007). Johnson & Onwuegbuzie (2004) suggest that research methodologists should still work with basic questions, such as problems of paradigm mixing, qualitative analysis of quantitative data and interpreting conflicting results. Several methodologists (e.g. Teddle & Tashakkori, 2003, and Creswell & Plano Clark, 2007) have started to create procedures for conducting mixed methods research. Validity is a specific problem which is being intensively discussed among the developers of the methodology, as Creswell and Plano Clark (2007) report, and it is also closely linked to the issues of combining data from various paradigms. (Validity is also an important methodological question in this study, and it is discussed in the following section.)

In this study, the aim was to use those methods that can best give a relevant understanding of the particular questions, and to keep in mind the limitations and possibilities of the methods and their epistemological background (Feuer, Towne, & Shavelson, 2002; Johnson & Onwuegbuzie, 2004; Maxwell, 2004; Strauss & Corbin, 1998).

4.4. Validity of the study

In this study, the main question of validation is how well the sub-studies together describe and explain ‘school’ in general. Further, validation is related to the authentic context of the sub-studies and issues around ICT; the studies are strongly situational and especially time-dependent. How well do the studies describe the phenomenon in other contexts? Are the conclusions of the study accurate and meaningful?

The theoretical framework for establishing the standards and criteria for validity in mixed methods is still being developed (Niglas, 2004). In this study, mixed methods were used to investigate the complex phenomena from various stakeholders’ points of view, but also to support validation, in the form of triangulation, which in this study was used as a means to combine different perspectives in order to give a fuller and more complete picture of the phenomena, as complementary compensation for the weaknesses of a single method (Erzberger & Kelle, 2003; Flinck, 2002). Linking the results of various studies is a controversial question: is it possible to combine different kinds of data to support the conclusions? Among others, Brannen (1992) has argued that data can only be understood in relation to the purposes for which they are created, and it is naive to assume that validity increases with combining approaches. In this dissertation, the different foci and the various kinds of studies – statistical comparative surveys and case studies – on the effects of ICT in school support the overall understanding and conclusion-making. The solution of using longitudinal studies gives a longer perspective to the phenomena. The data are used in a complementary manner, each study adding something new to the issues investigated.

4.5. Overview of the methods used in the studies

As an introduction, Table 1 presents the methodological solutions of the sub-studies. The detailed descriptions are presented after the table.

Table 1. An overview of the methods used in the studies

Study	Subjects	Research focus	Data collection	Data-analysis
Study I: Uses of New Technology Across Generations: Comparing the Development of Students' And Teachers' ICT Skills and Practices of Using ICT	494 and 365 teachers from 32 schools; 910 and 945 students from 6 schools	Students' and teachers' self-evaluated ICT resources, skills and use	A self-report questionnaire to teachers and students in academic years 1997/1998 and 1999/2000	Descriptive analysis, ANOVA comparisons.
Study II: Does gender have a role in ICT among Finnish teachers and students?	365 teachers from 32 and 945 students from 6 schools, 167 teachers from 9 schools and 495 students from 6 schools	The differences in ICT skills and use between genders and generations	A self-report questionnaire to teachers and students in academic years 1999/2000 and in 2002–2003	Descriptive analysis, ANOVA comparisons.
Study III: Intensive use of ICT in school: developing differences in students' ICT expertise	18 students in Länsimäki School	Students' activities, observed ICT competence and students' beliefs about expertise	Interviews, questionnaires, field notes, student products	Qualitative content analysis, Descriptive statistical analysis, cluster analysis
Study IV: Case study of Länsimäki School: development with ICT	Principal and teachers of Länsimäki School	Teachers' activities in classrooms, their observed ICT competence, and beliefs	Interviews, observation, field notes, questionnaires	Qualitative content analysis, Descriptive statistical analyses
Study V: Case Studies of Learning Objects used in School Settings	4 teachers and the students of each class, altogether 85.	Learning objects in ordinary classroom practices	Classroom observations, interviews, field notes	Qualitative content analysis

The respondents

The sub-studies represent diverse schools, teachers and students in relation to each other: Studies I and II are quantitative studies with unselected groups of respondents. Studies III and IV present one pilot school which, within the years of the ICT projects, carried out major improvements in teaching practices, as well as new working practices in the teacher community. In Study V, the teachers in the case study have good ICT skills and (somewhat various) pedagogical experience in teaching with ICT, but they work in ordinary schools, and the schools did not participate in any special ICT projects. Consequently, the sub-studies represent the situation of ICT adoption in education: there are high-level ICT pilot schools, individual motivated teachers with good ICT skills in ordinary schools, and then a large number of teachers in all kinds of schools. The students in the sub-studies represent two kinds of groups: in studies I and II, they represent an unselected group of respondents. In studies III and IV, they were a group of lower secondary school students who during the years studied in an ICT-intensive classroom with special emphasis on meaningful use of ICT in learning practices. In Study V, students were ordinary students in four classrooms. In this study, these students were not investigated directly.

Quantitative methods: comparative studies

The statistical analyses of self-report questionnaires were used in studies I and II to compare teachers' and students' ICT skills and usage, and the changes during municipal ICT implementation processes.

Study I was a comparative study, in which students' and teachers' ICT resources, skills, and usage were investigated statistically. Two questionnaires were constructed for the evaluation purposes in the Educational Technology Project of the City of Helsinki to investigate teachers' and students' ICT beliefs, pedagogical thinking and beliefs, as well as their practices, especially about using ICT. In this study, only those questions were used, which were the same in both questionnaires.

The questionnaires were sent to both groups twice, in 1997/1998 and 1999/2000. The groups of comparison were as follows: Male students I (N=454), Female students I (456), Male teachers I (122), Female teachers I (372), Male students II (472), Female students II (473), Male teachers II (110), Female teachers II (255)¹² in which I = the first phase of the study, the academic year 1997/1998, and II = the second phase of the study, the academic year 1999/2000.

In Study I, the quality of teachers' ICT competence differed from students' ICT competence remarkably, and a factor analysis could not be done in the same way for the both groups, because the factors Basic and Advanced ICT skills could not be constructed similarly. It became obvious that the culture of ICT was different among the two groups, and it is not possible to describe these cultures; as Ratner (1997) points

¹² There is a mistake in Study I Table 1. Male teachers in the second year (122), should be 110, and female teachers in the second year (372), should be 255.

out, comparing statistical differences is impossible in different cultures, and the nature of the culture has to be investigated with other methods.

It is obvious that the measurement tool, the questionnaires, represented mainly technology-related skills and technology usage, in which technology is not yet intertwined with ordinary practices. This is due to the timing of the research. For this reason the questionnaires are no longer adequate for investigating the skills and use of ICT in a wider context. However, the questionnaires were adequate when they were used, and the statistical analyses revealed for the first time the gender and generation differences as well as the trend in changes.

Study II was also a comparative study, in which students' and teachers' ICT resources, skills, and usage were investigated statistically. The study continued investigating the same phenomena as Study I, but the emphasis was more strongly on gender and generation (females - males, students - teachers) issues. The very strong increase in the use of the Internet took place during 1998–2002. For that reason, the self-report questionnaires used in Study I were further developed, and the questionnaires used later in Study II consisted of the Internet-related items, such as skills and activities. This was an improvement, providing a wider understanding of the role of ICT among the young and adults.

The first set of data of Study II was the same as the second set in Study I (teachers 1999 and students 2000). The second set of data were collected for evaluation purposes in the Educational Project in the City of Espoo in 2002–2003. The groups of this second set of data were as follow: Male students (N=227), Female students (268), Male teachers (42), and Female teachers (125).

In both studies, the comparisons were conducted using SPSS Statistical Software and analysis of variance (ANOVA) for testing the differences between the groups and Scefte's post test for testing the significance of the differences. A conservative significance level of $p > .001$ was chosen in the presentation of the results to reduce the effect of the large sample.

In both studies it is notable that the participants of the studies were not the same in the two phases investigated. This originates from the data collection procedures. Questionnaires were collected in chosen schools, but it was not possible to trace the individual participants (teachers and students) who had changed school. For this reason, the results describe trends of the groups, not changes in the skills and practices of individuals.

Self-report questionnaires and social desirability

An important limitation of Studies I and II was that the students' and teachers' practices and skills in using ICT were measured using their self-assessments. Self-report questionnaires have limitations: participants know that they are participating in a study, and they might want to please the researchers or hide something. ICT is expected to be

especially strongly emotionally loaded: for teachers, there was an official interest in using ICT in school, but many teachers did not have the necessary technical or pedagogical skills. Do they overestimate their skills and, e.g. usage in education to please the researchers (and the municipal administration behind the research) or underestimate their skills? Women appear to have a propensity to underestimate their competence (Nurmela, 1998), and probably this is also true among female teachers. For male students, ICT competence is related to the development of gender identity (Facer, Furlong, Furlong, & Sutherland 2003; Stepulevage, 2001), and teenage boys tend to overestimate their competence, as suggested in Study II. The issue of social desirability was considered when designing the original self-report questionnaires (Hakkarainen et al., 2000), but no way of discounting it entirely was found.

Case studies: longitudinal ethnographic case studies and a multiple case study

The dissertation consists of two longitudinal ethnographic case studies and one multiple case study. To investigate the implications of using ICT intensively among students during a three-year period at lower secondary school, we used a longitudinal case study (Study III), in which the class of the students formed the case. To study the changes and the diffusion of ICT in the teacher community we used a longitudinal case study (Study IV), in which the teacher community was the case. To study the activities and knowledge practices and the affordances of learning objects in authentic teaching/learning sequences, we used a multiple case study (Study V) in which one teaching/learning sequence in a classroom formed the case. Altogether Study V consisted of four cases.

A case study was chosen for these studies to investigate empirically contemporary phenomena within a real-life context, especially because the boundaries between the phenomena to be investigated and the context were not clearly evident. At the beginning of the research process, it was difficult to define, which were the conditions and the basis for the development and which were the consequences or decisions of previous activities. The three case studies (Studies III, IV and V) represented a unique case (Yin, 2003) because of the extensive ICT resources available, and because of the continuous support for teachers. These were instrumental case studies, in the sense that they facilitated understanding about the phenomena, allowing generalizations and theory development, so the interest was not just in the case itself (Eisenhardt, 1999; Stake, 2000; Yin, 2003).

Interaction with the teachers in all three studies was essential. The researchers had a close relationship with the participating teachers: it was typical to talk with teachers about their teaching activities, e.g. after an observed lesson. Teachers also read and commented on the final written analyses. Teachers were owners of their processes, not only objects for the research. It is evitable that in such real-life classroom practices research is also a means for teachers' development in work, and the researchers acted as a mirror for the teachers, as well as experts in educational theories, to discuss with. Interviews were an important source of data in each study. Interviews meant interaction and social constructions, reflections of the situations, not "objective data"

mirroring the objective world (Fontana & Frey, 2000; Kvale 1997). The knowledge gathered in the interviews was inter-relational and structural (Kvale, 1996), the context, the situation, even the personal relationships affected the answers, and these are "a potential source of bias, error, misunderstanding, or misdirection" (Holsten & Gubrium, 2004, p. 141).

The role of the researcher/researchers varied. In Study III, one researcher supported and even initiated teachers' activities in the classroom. In Study IV, the researchers similarly had a strong, consultative role. In Study V, the researchers were mainly observers; the teachers discussed the activities in the classroom with the researchers mainly after each lesson, which, however, might have had some effects on the following lessons.

Longitudinal ethnographic case studies

Studies III and IV were longitudinal studies. They had several common characteristics as an ethnographic study. A case study and an ethnographic study closely resemble each other, e.g. in the variety of data collection, but there are also differences; every case study is not an ethnographic study. The studies of this dissertation are case studies but they have some characteristics typical of ethnographic studies especially in the methods of data collection. One important difference between an ethnographic study and a case study is that, in the latter, theory development is essential as part of the design phase (Yin, 2003). This was also true in these sub-studies. In Study III, the previous research about adult expertise guided the choice of data, which was, however, collected with ethnographic techniques. Similarly, in Study IV, the researcher used a theoretical basis from school development research (e.g. Senge et al., 1994; Fullan, 1993), but the data collection followed an ethnographic method¹³. The construction of research questions, data collection and theory building formed an iterative process, each one having an effect on the next cycle of the process. The role of theory development was emphasized (see abductive methodology: above; Paavola, 2006).

An ethnographic method of data collection, analysis and use was chosen for the case studies because the context, intensive use of portable computers, was new to both teachers, and students, as well as to the researcher, and by entering into the everyday life of the school it was possible, more than with other methods, to get an understanding of the activities, interests and behavior of the subjects (Feuer et al., 2002; Tedlock, 2000). Both studies were conducted in one place, a school, and the focus of the observations was on that specific school culture; the (mainly one) researcher had a close connection to the school, and she spent several one-week periods in everyday school life trying to get an interpretative understanding of the school and classroom cultures and communities. The methods used were tools to help the researcher grasp the phenomena as a whole in a hermeneutic way (Flick, 2002;

¹³ I use 'method' but there are also researchers who would suggest in this context 'technique', reserving 'method' for "pure" ethnographic research (e.g. Wolcott, 1999; see also Creswell & Plano Clark, 2007).

Wolcott, 1999). The setting of the studies was important for the research questions and the process. The research questions were constructed during the process, reflected on and re-formulated after interpretation and a better understanding of the phenomena (Giles, 2004; Wolcott, 1999). In ethnographic research, the role of the gatekeepers is important (Giles, 2004), and that was true also in Studies III and IV. In these studies the principal and the ICT teacher were the most important persons providing help to gain access to the school and to the classroom in particular. In addition, official gatekeepers were the representatives of Vantaa City educational office who approved and supported the project and the study. The data consisted of a field note diary, a large sample of notes about discussions with teachers and students, recordings of teacher meetings, teachers' task sheets for students, and students' results or products of tasks (or copies of them), as well as teacher and student interviews and questionnaires. The ethnographic method in these studies was both traditional: (mainly) one researcher participated in the situations and her personal interests guided the focus of the observations (criticized, e.g. by Eisenhart, 2001); and "modern": the researcher conducted some parts of the study in the context of an international research program (OECD/CERI), or together with another researcher (the computer-supported collaborative learning projects).

The researcher's own beliefs and hopes are often present in the studies. I have to admit that especially in the beginning of the research period, when the first intensive three-year process started, I had a strong ethos of improving learning and teaching using new technologies. This idea guided my interventions in the school, e.g. teacher training activities, and also my interests on observations. On the other hand, I was a very inexperienced researcher and, for that reason, I tried to collect all possible data, in a true ethnographic way, which probably somewhat balanced my idealistic attitude. In these studies, the "reliability" requirement was met as in traditional qualitative case studies, e.g. by opening the classification (in Study III) or by using triangulation (in Study IV).

The data of Study III were mainly qualitative but they were modified to become quantitative, and the final cluster analysis was a combination of the quantitative scores and the qualitative data.

A multiple case study

Study V was a multiple case study, where the cases were like experiments in which the theory development was a part of the design phase, and theoretical presumptions guided the focus of the observations (Yin, 2003). Theories were also used as mirrors for understanding the case. The use of learning object(s) (LOs) was essential in each case, and the teaching and learning arrangements varied depending on the use of the LO(s). In order to increase comparability, researchers wrote guidelines for conducting the studies. The process of this multiple case study followed nicely those presented by Yin (2003): the theoretical background guided the design of the cases; these were conducted and then analyzed and reported, and after each case was reported a cross-case report was written.

5. OVERVIEW OF THE ORIGINAL STUDIES

Article I

Ilomäki, L., Hakkarainen, K., Lakkala, M., Rahikainen, M., Lipponen, L. and Lehtinen, E. (2002). Uses of New Technology Across Genders and Generations: Comparing the Development of Students' And Teachers' ICT Skills and Practices of Using ICT. In K. Fernstrom (Ed.), *Proceedings of Third Conference on Information Communication Technologies in Education*. (pp. 539–548). Athens: National and Kapodistrian University of Athens.

The purpose of the study was to examine the development of skills and practices of using information and communication technologies (ICT) among students and teachers in schools in Helsinki in 1997/98 and in 1999/2000. The interest was to examine ICT resources both at school and at home, self-reported ICT skills and ICT usage for learning and teaching. The aim was, further, to investigate whether and how skills and practices of using ICT in different groups of students and teachers differed from each other during the three-year period. A self-report questionnaire was constructed for assessment. The participants were 494 and 365 teachers from 32 Finnish schools, and 910 and 945 students from six lower and upper secondary schools.

The results indicated that the average level of both teachers' and students' self-reported ICT skills improved, but females' self-ratings on several categories were lower than those of their male peers at both times of assessment; only word processing was evaluated to be on the same level. Information networks skills showed an extraordinary development: in the second survey especially female students' self-evaluated skills in www-activities were higher than in the first survey.

The increase in the average level of students' use of computers in studies within only two years was remarkable, although it remained at quite a low level. Teachers' estimation of their use of ICT in teaching was higher than that of students; probably students would like to use ICT more than they do, and for this reason they underestimate the usage. Teachers may feel pressure to use more ICT in education, so they overestimate the usage. It was suggested that more effort should be invested in facilitating female teachers' and students' use of ICT, and especially female teachers' development of their ICT skills. One encouraging result was that male and female students report using ICT in school almost equally.

Article II

Ilomäki, L. *Does gender have a role in ICT among Finnish teachers and students?* Manuscript submitted for publication.

The purpose of the study was to investigate the digital divide between genders and generations in school, i.e. between teachers and lower and upper secondary school students in Finland, and to investigate the role of school in supporting the use of and

the competencies in ICT. The phenomenon was investigated by collecting data about the access to ICT at home and in school, the ICT skills, and about the usage of ICT. The study was conducted in the context of two municipal school-related technology projects by comparing statistical data in 1999–2000 of 365 teachers and 945 students, and in 2002–2003 of 167 teachers and 495 students. Data were collected by self-evaluation questionnaires.

The results revealed that the level of available ICT resources was significantly higher in the second survey than in the first one: practically everyone had access to a computer in school and almost as many also at home; especially access to the Internet was much more frequent in the second survey than in the first, and about 2/3 of the respondents had access to the Internet both at school and at home. Female teachers more often have a computer available in the classroom than males; this has the effect of making learning a natural and easy way to use ICT in pedagogical practices. ICT skills were connected to both generation and gender. Teachers were very familiar with some traditional applications, students with new applications such as graphics. In general, male teachers and students estimated their skills on a higher level than females, but in the second phase, female students' competence and use of ICT were close to those of male teachers. Self-reported activity in sending e-mails and searching the Internet were on a similar level in each group, but the usage of technical Internet applications showed a male dominance. The use of ICT in the classroom was on a low level; both from teachers' and students' perspectives, and students reported using ICT for studying quite seldom. The data also revealed a distinction between school use and leisure time use. The leisure use was more active and inspiring than the school use. It appears that school has not used all the possibilities of new technology to transform the existing teaching and learning practices. According to the study, students and many teachers, too, have adequate technology skills and even resources but the change is dependent on factors other than just technology.

In future, communicative ways of using ICT, such as e-mail, wikis and blogs, will probably reduce the differences between the genders and generations, although the gaps between the genders and generations in technical competence will remain.

Article III

Ilomäki, L. & Rantanen, P. (2007). Intensive use of information and communication technology (ICT) in lower secondary school: Development of student expertise. *Computers and Education*, 48, 119–136.

The purpose of the study was to examine the effect of intensive use of portable computers on the development of students' high-level computer skills (student expertise) in information and communication technology (ICT), the characteristics of these high-level skills, and the characteristics of the implementation of ICT that supports the development of students' skills. The background to the study were the common comments on ICT skills and competence among teenagers; their expertise was relative and situational, more a role in a community than a narrowly defined

mastery of domain knowledge. The study was a follow-up study longitudinally examining student ICT expertise in the natural school and home environment from several perspectives: 1) whether students appeared to have a well-organised body of domain-specific knowledge in ICT, 2) the relationship of higher-order knowledge and skills to some individual variables, such as metacognitive consciousness, interest and motivation to develop one's own competence, 3) to what extent the student experts participated in authentic expert cultures outside their school, and 4) the effect of their community of fellow-students on their developing expertise.

Eighteen lower secondary school students had portable computers for three years to be used both at school and at home. The teachers focused on facilitating students' complex problem solving, inquiry learning and other methods of process learning, which relied on intensive use of ICT. Students used the portables intensively also at home, both for homework and during their leisure time. Multiple methodologies were used during the three years. The data consisted of semi-structured interviews, self-evaluation questionnaires, and qualitative analyses of students' written productions.

The results of the study indicated that the intensive use of ICT and the process-oriented learning environment supported the development of student expertise in ICT. In the analysis, three groups were identified based on the following variables: Basic ICT skills, Advanced ICT skills, Participation in large ICT projects, Assessment of one's own expertise, ICT tasks and Future plans. The groups oriented themselves differently in ICT: student experts (=6), of whom 3 were technically oriented and 3 socially oriented, advanced users (n=8) and non-interested users (n=4). The student experts differed from the other groups especially in their good computer skills, and professional orientation to ICT; they were often relied upon as experts by teachers and other students; they had undertaken ICT-related tasks outside the school; and they had future plans in ICT. The student expertise was the result of a combination of school-related ICT teaching, the intensive and flexible learning environment at school, and individual motivation and interest.

Article IV

Homäki, L., Lakkala, M., & Lehtinen, E. (2004). A Case Study of ICT Adoption within a Teacher Community at a Finnish Lower-Secondary School. *Education, Communication and Information* 4, 53–69.

The purpose of the study was to investigate how teachers adopt information and communication technology (ICT) as a pedagogical tool, what consequences the intensive use of ICT has for teaching practices, and how the use of ICT diffuses in a teacher community.

Länsimäki School, a lower secondary school, was an ideal case for a longitudinal instrumental case study to advance understanding of the investigated phenomena because the staff of the school was willing to develop the use of ICT in education and was also motivated to collaborate with the researchers. The study combined the

longitudinal data of three sub-studies, which were conducted during the years 1994–2001. The first sub-study in 1994–1997 was close to an ethnographic study. Students of a 7th grade class were given laptops for their personal use throughout the three years of lower secondary school (the same project as in Article III). The aims were to discover what kinds of experiences students would have with the laptops in school use, and what changes would take place through computer use in instruction, as well as in learning. The data consisted of structured interviews with the teachers and the principal, notes of informal discussions with individual teachers and of project meetings, a researcher's logbook during the project, classroom observations, and teaching materials used by the teachers during the project. In the second sub-study, the CL-Net project (Computer-Supported Collaborative Learning Networks in Primary and Secondary Education) in 1998–2000, the aim was to develop learning practices towards collaborative knowledge building and progressive inquiry. The data were collected from three classroom projects and consisted of interviews with two teachers, a questionnaire from seven teachers participating in the project, notes of the project meetings, and a conference presentation of one teacher. The third sub-study, the OECD Evaluation in 2000–2001, was an explanatory case study for the international study about how ICT relates to educational innovations. The design of the data collection and the analysis were based on the guidelines of the OECD study (Venezky & Davis, 2001). The data consisted of interviews with the principal, the technology specialist, and representatives of teachers, students, and parents. In addition, the data consisted of notes of informal discussions, examples of students' work, a teacher survey about ICT practices (N=15), classroom observations in note form, and curriculum, project plans and www-pages.

The results of the study indicated that the intensive use of ICT had several effects on the teacher community. Almost all teachers acquired the necessary technical ICT skills, and the majority of teachers used ICT with students. The pedagogical practices varied, depending on the teacher's interest and pedagogical thinking; several teachers adopted advanced teaching methods and they emphasized authenticity, student-centred and inquiry-based learning activities, which were also appreciated by the students. The important elements for successful implementation of ICT were the key persons: a respected and devoted ICT teacher, a principal who support and resources and created an atmosphere favourable for development and change, and a group of innovative teachers. The university support was also important for conducting and sustaining the ideas and plans. During the years of the study in school the reflective practices among the teacher community became both an important result of the conscious implementation process and a force for maintaining the development.

Article V

Ilomäki, L., Lakkala, M., & Paavola, S. (2006). Case Studies of Learning Objects used in School Settings. *Learning, Media and Technology*, 31, 249–267.

The purpose of the study V was to investigate the role and characteristics of virtual learning objects in selected classroom cases. Four Finnish cases represented such

pedagogical approaches as student-centeredness, process orientation and collaborative inquiry. The case study approach enabled the investigation of concrete practices in using learning objects in ordinary classroom settings. These cases consisted of several lessons, divided into three-to-five week periods. The four teachers participated in the study voluntarily, and their experience in technology-related pedagogy varied from a very good and long experience to their level of an ordinary Finnish teacher with some experience and basic ICT skills.

The goal of the study was to examine the interrelatedness of the pedagogical practices and the characteristics and affordances of the learning objects, in order to understand how learning objects can support the development of advanced pedagogical practices in schools. The data used were qualitative, consisting of the participating teachers' agendas, and observations and video recordings during classroom sessions. The observations were pre-planned to focus on 1) the teacher's activities in defining, designing and organising the tasks, as well as structuring and phasing of the lessons; 2) students' activities and tasks; 3) ICT practices; 4) learning objects, and 5) the atmosphere in the classroom.

The results indicate that learning objects were mostly used as exploration tools, information resources, assessment models and objects of discussion. An expert-like use of knowledge was characteristic in the pedagogical settings, especially when the teacher was experienced with using ICT in teaching. However, not all the learning objects supported such practices, thus preventing the teacher from reaching the intended pedagogical aims. The teacher's role and competence in organising, structuring and guiding the whole process was crucial: to implement a learning object into a teaching process is a challenge for the teacher's technical competence, subject domain expertise and pedagogical thinking and competence. It is necessary to continuously evaluate the role of new technologies; it is important that the development of educational technology is an iterative process between pedagogical theories and practices and the new technology applications.

6. FINDINGS AND CONCLUSIONS

The aim of this study is to investigate the effects of ICT in school from multiple perspectives to find out how the various elements influence in school, elements such as students' and teachers' ICT skills and usage, ICT in teaching and learning practices, ICT adoption within a teacher community, and an overall change process in school. The long duration of the study has allowed us to draw conclusions from a longer time perspective, which has been an advantage, allowing us to avoid the technology hype, which exists even in the educational branch, and to follow the development of the trends instead of focusing only on snapshots. The focus has been on school level, keeping in mind socio-cultural and political dependencies and interactions.

Results of ICT-related goals

The results of this study (Studies I, II), (as well as the international surveys, Eurydice, 2005; Korte & Hüsing, 2007; Pedersen et al. 2006) indicate that, in Finland (and in other frontrunners of ICT in education) the technical resources for using ICT both at school and at homes are very good. In general, students are capable and motivated users of new technology. It is remarkable that these skills and attitudes are mainly based on home resources and leisure time use. School teaching has probably had the impact on female students' skills, although it has improved especially ICT working practices also among boys for whose skills the leisure time use has been more important. In general, students have skills to use new kinds of applications and new forms of technology, and their ICT skills are wide, although not necessary adequate; the working habits might be ineffective and even false.

Teachers' skills are more heterogeneous. There are teachers with high-level technology skills; they are often male and young teachers. The large majority of teachers have sufficient skills for everyday and routine working practices, but many of them still have difficulties in finding meaningful pedagogical use for technology. There is still a small group of teachers, more often middle-aged and older females, who lack even basic ICT skills, which is probably a question of motivation and interest (see also Korte & Hüsing, 2007, for the latest, and similar, results). The intensive case study (Study IV) indicated that the majority of teachers acquired necessary technical ICT skills, and they also used ICT with students. For these teachers, the projects offered a possibility for learning new skills and competences intertwined in the work, often also supported by external experts and a collaborate teacher community; a possibility that the "ordinary" teachers, participants of Studies I and II did not have.

One consequence of students' good ICT skills is the development of student expertise, investigated especially in Study III, but which already became apparent in the results of Study I. Student expertise develops in a beneficial interaction between school guidance and challenges, and individual interest and activity. In ICT pilot schools, this can be deliberately supported, as Studies III and IV indicate, and in many schools there are signs of such support when students have responsibilities for, e.g. a

school's ICT infrastructure, but this is too seldom understood in a school, mainly because of the traditional culture and roles of teachers and students.

The difference and especially the change of the differences between genders in ICT skills and usage is a time-related phenomenon which became evident during the period of the studies. Studies I, II, and III indicate that there is a gender gap: males show better skills especially in purely technical issues. Female students and young female teachers estimated their skills as close to the skills of males, and also their use of ICT increased significantly. With time, the technology has become less technical and its communication and creation affordances have become stronger, easier to use, more popular and motivating. This has increased females interest in technology, and female students and younger female teachers use ICT in their ordinary practices quite naturally. For research, the question of younger females' digital competence is an interesting topic: they are on the boundary between traditional technical and male-associated technology and the new communication and community -associated culture of technology.

Community-related goals

The results of Studies IV and V (from individual teacher's perspective) reflect teachers and a school that are interested in ICT. Although in the school investigated (Study IV) all teachers were not similarly motivated, some teachers were even against ICT, there was a school-level interest in and motivation to improve education with ICT. In Study V, the participating teachers similarly had their own interest and even (very) good competence in ICT and in the pedagogical use of ICT.

Teachers in Study IV were, in general, helped in creative and deliberate ways in their implementation processes, which considerably helped the adoption of ICT. All teachers participating in the various projects conducted their own pedagogical practices with ICT, and increased the use of ICT; it became an ordinary tool for the majority of the teachers. During the first project, the adoption was easy and smooth; teachers' personal interests and the school community's goals for implementing and applying ICT blended into a reciprocal commitment. Such teachers who did not participate in any of the intensive ICT implementation projects, were less interested or motivated in applying ICT, but even many of them regularly used ICT, although not necessarily often.

There were several essential elements that helped the adoption and improvement of ICT-related pedagogy, as the results of Study IV show. Teachers had their own motivation, and they had external support from 1) the key persons of the school: the committed principal and the ICT teacher; 2) from the teachers' community; 3) external collaborators: local school administration and university consulting and research. In Study V, teachers organized and conducted the processes independently (however, reflective discussions were conducted afterwards), but they, too, had support and guidance within the Celebrate project; they did not work in isolation.

The development of the community (in Study IV) came to resemble those features of a learning organization. The community became a conscious pedagogical entity with shared goals, plans and interests. Many key teachers increased their external networking, which also enlarged their teacher role; two of them even left the school to work as experts in other educational contexts. The longitudinal projects investigated in Study IV indicated that the results are enduring, although it is a challenge for a school to maintain the collaborative and well-functioning pedagogical community.

Learning environment and teaching practices -related goals

Technology-related learning environments changed remarkably during the duration of this study mainly because of the rapid change in technological infrastructure. The school in Study IV could adapt to changes and also plan and use the new possibilities for improving the learning environment in a more open direction for all students. The study began with a pioneer project using personal laptops in only one class, but ICT became an ordinary feature also in other classes and teaching. Similarly, in Study V, ICT was an essential element of the teaching practices, and it was familiar to three of the four teachers. However, technology also continuously created problems and difficulties, and teacher's good ICT competence is needed, as especially the results of Study V indicated. Both studies showed that ICT was used in various ways: 1) it was a tool for delivering material or for practicing a specific learning content, which is *a traditional way* of using ICT; 2) as a tool for supporting collaboration or knowledge creation, which was *a change from the previous teaching practices*; 3) as a tool for structuring teaching/learning processes, which was *a change from the teacher's management practices*, and 4) as a content for studies; this 'academic' knowledge helped them to use it also in learning practices and to develop high-level adaptive expertise (in the laptop project). This way of using ICT is *a change in the curriculum*. Although the affordances of technology are important, and they suggest and support certain activities, more important is the teacher's understanding of and competence to use the affordances.

Studies IV and V (also Study III implicitly) indicate that the results are promising concerning classroom activities; there are true changes in teaching practices. In study IV, many teachers adopted student-centered and collaborative, inquiry-oriented teaching practices that are believed to promote meaningful learning. In Study V, the practices supported such as students' authentic activities, independent work, knowledge building, and students' responsibility. This is, indeed, strongly dependent on the ICT-related pedagogical competence of the teacher. Teachers with good ICT-related technical, organisational and management skills as well as interest in pedagogical use of ICT conduct student- and knowledge-centred activities at classroom level, as indicated in Study V. Teachers of the both studies were involved in boundary crossing, and, in this sense, they had opportunities to negotiate new meanings through collaboration which resulted in pedagogical innovations. Such innovations were fulfilled regularly, they were various kinds, larger and integrative learning projects or smaller ones, and they usually were a combination of new technological possibilities and, for the teacher(s) new teaching practices.

In Study IV, daily practices of some teachers still reflected a rather traditional teacher-centred approach. As a matter of fact, very few teachers ever represented solely e.g., the knowledge building approach; teachers used various approaches or mixed them, based on the situation, teaching and learning goals, and on their pedagogical and technical competence; this was true also among teachers in Study V. In general, changes towards pedagogical improvements are even in well-organised developmental projects slow, as Study IV shows.

7. REFLECTIONS AND IMPLICATIONS

Diverse ICT skills – diverse cultures

The differences between young (students but also the youngest teachers) and teachers is characterized by Selwyn (1999) as different computing identities; it is possible that these identities will grow even further apart because many technology affordances are not familiar to teachers, or older generations in general. Such examples are, e.g. applications which support distributing personal information – even playing with identities – and networking in the Internet, in MySpace or Facebook or blogs. Similarly various wiki-applications are a challenge for the “copyright generation”: everything is for free and the improvement is in collective responsibility. Technology is not essential, the social forms of it are in the centre (Buckingham, 2007). These new applications are not only tools that replace some previous manual practices; they change many of our existing conceptions, from own cultural basis to values, attitudes and practices; and, as Bryant (2007) reminds us, it is the social affordances, not the technology itself, that is new and exciting. The very different conceptions that generations have about technology leads, in the worst case, to a digital gap in education; the technology used in school is boring, ineffective, and it does not provide the competence needed for using advanced technology in learning. We do not need to take for utopia of social software (continuing the utopias Lehtinen has presented, 2006), but as the results of this study, and e.g. Reeves (2008) suggest, there is a need to make changes in the way technology is used in education to better take into account the digital competence students have.

Harris (2002b, p. 62) writes that “school improvement is essentially about constructing a better match between schools and young people”, but students are usually not regarded as essential actors in school improvement processes. This is true also in ICT implementation. In practice, students are objects of the teaching practices, and their necessary competences and outcomes are discussed and evaluated against the supposed and expected needs of the information society. Giving student experts a new role in school could be one step towards new structures, roles and responsibilities in one area in school, ICT, and towards opening up the school hierarchy to students. For research, the phenomenon of student expertise offers a new object for investigation: it has similarities with the traditional expertise of adults, and it is grounded in adaptive expertise, but it lacks prolonged formal education and practice. It is also clearly a result of information technology, not only as an inspiring content but also as offering the new functionalities: virtual networking and a free practicing environment. The growing number of open source communities will produce more young ICT experts, and this expertise has a similar basis to that described as student expertise in Study III.

Pedagogical changes occur only in favourable conditions

Although the promising results of this study show that ICT has been a major possibility for school and classroom level improvements, in general it has not been a catalyst for change except in the schools where ICT has been adopted to support necessary

pedagogical improvements; in Study IV the school was in this optimal situation. The expectations for ICT were overestimated: ICT was thought to change classroom practices, teachers' work, even their pedagogical conceptions about teaching and learning, but these changes did not come about. Fullan (2001a) calls this a major change for re-culturing: transforming the culture and changing the way of doing things is one of the main aspects in understanding change. In ICT implementation processes this was not understood or taken into account. There are expectations, even pressures and demands for change, but also a limited amount of support and, moreover, non-appropriate support. Nor have the existing structures of education and educational institutions been re-structured. Even in schools with experiences of pedagogical improvements and technology, teachers face diverse problems when integrating new pedagogical practices and new technology as e.g. a study by Lakkala et al., (2007) showed. The transformation of learning with web-technologies demands change in teachers' conceptions about learning and knowledge, and in their skills in implementing new practices.

In addition, the theoretical ideas have been difficult to implement in practice because the spirited ideas of theorists have been too immature (Lehtinen et al., 2001); there was a gap between those practically oriented administrators and educators who promoted the use of computers at classroom level and those researchers who were concerned about the school change, without computers.

As a result of the implementation of ICT, there are two kinds of "ICT stories". In the large majority of schools, ICT has been mainly implemented to assimilate in the inevitable future with educational technology, and the process has been more or less top-down, without a strong commitment of the schools or the teachers. In successful pilots, the way of implementing ICT focused especially on the needs of that specific school and supported the internal improvement of that school; many of the effective factors for sustained school and classroom improvements, as presented, e.g. in Harris (2002a) and Fullan (2001a) are successfully taken into account. Studies of school improvement have indicated that schools have benefited by becoming professional learning communities in order to successfully meet the developmental challenges of building school capacity, which consists of teachers' knowledge, skills and dispositions, professional community, programme coherence, technical resources and principal leadership (Condie et al., 2007; Fullan, 2001a; Hargreaves, 1999; Harris, 2002a; Hord, 1997; Newmann et al., 2000). For research, it is a challenge to investigate the gap between high-level aims and expectations and the ordinary practices, and further, to improve the support for "ordinary" schools so that the ICT implementation will, even in these schools, turn into a true process of pedagogical improvement. There is research about the adoption and implementation of technological innovations: it now needs to be disseminated to all schools. In addition, we should find out what is sustainable and pedagogically appropriate transformation, and what is only apparent technological hype. In the question of technology this is especially important to avoid expensive experiments which lead only to teachers' and other school staff's frustration.

For better and more use of new technology, the teacher's role and identity need to be re-thought. Participating actively in face-to-face and virtual networking in communities is one of the prerequisites and possibilities for professional growth. This is reflected e.g., by Cobb, McClain, de Silva Lamberg and Dean (2003) who suggest distributed teaching to help teachers share and reflect on their teaching practices, and Putnam and Borko (2000) suggest bringing researchers and teachers closer to each other which has been one of the success factors in ICT pilots. It was also noticed that teachers benefited from this networking professionally. Barab, Barnett and Squire (2002) prove that those who are at the boundaries within the community have special opportunities to establish innovations.

An issue to be discussed and solved by all participants in the educational field, researchers, administrators and practitioners, is *how school can manage the rapid and continuous change in technology*. The existing structures and practices in schools do not promote critical reflection, personal adoption and school level implementation of new technologies to improve working, teaching and learning practices.

The value of ICT in education

Finally, an important remark: Is technology always for the good? During the years of ICT implementation there have been teachers, and other school-related persons, who have criticized the role of technology in education. It has been easy to neglect criticism in schools and among teachers as change resistance, as it has sometimes been, but there is also relevant criticism and skepticism about the use of ICT. In the survey in 2006 one fifth of teachers did not believe that using computers had significant learning benefits for students, and these teachers were from both the countries leading the use of ICT, and from countries lagging behind (Korte & Hüsing, 2007). This was, indeed, also strongly connected to the age of the teacher: older teachers were more doubtful. This might prove to be an unfair emphasis on technology; the basic task for school is to help student to become experts in learning, instead of becoming just an expert in school-related activities, as Bruer (1993) emphasized. Concentrating too much, or at the expense of pedagogy, on technology, hides the need for improving pedagogy, in areas such as, for example, more efficient and meaningful information-processing and knowledge-creation skills. The often presented statement about improving students' lifelong learning skills remains empty without changes in ICT use in teaching practices. Basalla (1987) proposes that the concept of technological progress is based on assumptions in Western culture such as the belief that technology development is always an improvement, and that the advancement of technology directly contributes to the betterment of our lives. Although these assumptions have been criticized and questioned over the years, they have had a remarkable role in the implementation of ICT into education. I agree with Selwyn (2002) who stated that it is essential that the myth of the omnipotent teaching and learning machine is challenged by those within the educational community and that computers are (re)constructed and (re)contextualized along more appropriate and realistic lines. Future development should concentrate on the transformation of teaching and learning practices to better meet the challenges of modern society – and moreover, the children of the future.

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