Information and communication technology in education: Desires, promises, and obstacles

Erno Lehtinen
Faculty of Education, University of Turku, Lemminkaisenkatu 1, 20014 Turun Yliopisto, Finland, Erno.Lehtinen@utu.fi

Key words: communication skills, learning theory, social interaction, change, research

Abstract: Rather than a narrow inter-relatationship focused on technical skills, the challenge of ICT for education lies in the new types of knowledge that are opened through the technology. Complex problems in a world of rapid cultural and technological change, a re-consideration of styles of working, and new types of communication challenge both society and education. The focus of research has shifted to the social interaction when computers are used as part of the new learning environment. Yet despite promises of more effective learning, the reality is that learning differences are measurable mainly in experimental or special project classrooms. Change in regular classrooms has proved elusive. Recent evaluations of teachers' responses to the pedagogical challenges illustrate the need for more effective implementation and dissemination strategies.

1. THE INFORMATION SOCIETY AND THE CHALLENGES OF EDUCATION

Education, learning and teaching appear in all recent national and international documents where attempts have been made to outline the road to the information society. Two different approaches to the skills needed in the information society are currently being discussed. The narrow interpretation focuses on the need to train citizens to use technical tools such as computers, information networks, multimedia and virtual realities that constitute the most concretely visible part of the information society. In

The original version of this chapter was revised: The copyright line was incorrect. This has been corrected. The Erratum to this chapter is available at DOI: 10.1007/978-0-387-35499-6_29

D. M. Watson et al. (eds.), *Communications and Networking in Education*

many countries the official information strategies of education highlight the importance of acquainting students with these new technologies.

Alongside this narrow interpretation of the information society, which concentrates on technical equipment and its use, there is also a wider view, especially when considering the challenges and possibilities in education and training. We must consider the profound qualitative changes in people's lives brought by the information society. Profound changes in the cultures of work and know-how are connected with the rapid construction of the electronic industry, the emergence of a digital and global economy and the revolutional development of different media (Negroponte 1995; Tapscott 1996). It is impossible to predict these changes accurately, but based on the most advanced working life practices and visions provided by futurology, we can outline some trends in the ways work is changing and assess the competence requirements related to these changes.

Knowledge is the most critical resource for social and economic development in the advanced information society, and distributed expertise and networked activities more and more characterise the emerging types of work. Skills of independently searching, producing, and managing knowledge will be essential for thriving in the emerging knowledge society. The skills needed include the ability to solve increasingly complex problems in a variety of knowledge-rich domains, to participate in knowledge work, and to engage in various networked activities. Every citizen will need to be able to engage in education and professional development throughout his or her life.

In the modern knowledge organisations, practices of facilitating knowledge creation and sharing of knowledge are considered to represent the most important competitive factors. Modern organisations do not only deal with content of knowledge (having relevant and updated knowledge) or application of knowledge (using knowledge and innovations in an effective way), but also with the organisation of work with knowledge in a way that facilitates continuous knowledge advancement and supports the sharing of intellectual achievements among members of the community.

As a result of technological development, significant changes in the structures of work are taking place. This can be seen in the growing importance of information-based services in particular, or, to use different terminology, symbolic-analytical services. Although the significance of information-based work will grow, the importance and need for other kinds of activities – routine work and personal services – will remain. On the other hand, some visions of the information society assume "the end of work" (Rifkin 1995), meaning that a relatively substantial proportion of the population will not do salaried work in the traditional sense. Discussions of the educational and training needs of the information society have usually been tied to the demands of information-based work. However, the perspective should be expanded to include opportunities for basic education and lifelong learning also for those who become excluded from this type of work. Some form of selection or tracking is an inevitable part of education, but it is essential that such selection to shorter educational tracks does not effectively suffocate a person's learning skills and motivation and thus exclude these people from the active participation in the information society. As a matter of fact, it is even more important to pay attention to the development of learning skills and motivation for continuous learning among those people who do not have the opportunity to experience learning challenges and to use rich learning tools as a part of their daily work.

The information society is not reflected in our lives only through work, for our entire everyday environment is also undergoing similar changes. Ensuring our development and well-being outside of work requires us to develop our information society skills. When examining the information society, we need to widen our perspective: rather than looking narrowly at information society skills and taking a work-centred approach, we need to broaden our view to take into account the whole spectrum of life. On the other hand, the tools that are brought by the development of the information society offer many opportunities for new kinds of participation and learning taking place outside of educational institutions. People's relationship to ICT can be considered from the perspective of their entire lifespan by looking at the various roles an individual has at different stages of life: in their working life, leisure time, as a member of a family.

By surveying present and future trends, we may identify at least the following four new challenges.

First, managing complex, ill-defined problems and rapid change is emerging as an increasingly central strategy for 'survival'. Increasing information does not unambiguously make our lives more manageable, but in many cases leads rather to growing uncertainty. With the tools provided by technology, people attempt to steer and control their environments with increasing efficiency, but at the same time the social, cultural and economic environment shaped by that technology is becoming more difficult to control and to predict. Formal and precisely defined knowledge alone is not enough for managing this complexity, as we need to be able to combine the knowledge traditionally transmitted through education to the informal knowledge which develops in connection with various activities and which usually cannot be accurately described or defined (Lehtinen and Rui 1996). Rapid changes in social and political practices and in people's social and technological operating environments require that both individuals and organisations flexibly restructure their old practices and thought models and learn continuously. This in turn calls for a more developed understanding of knowledge and how it is constructed in individuals and in social practices. Learners must adopt a learning orientation which aims at surpassing their own expertise limits and acquiring high-quality learning skills that are manifested as the ability to adapt their expertise and learning to the requirements of their present activities (Bereiter and Scardamalia 1993).

Secondly, a new operational model is emerging in production, scientific activities, administration and everyday practices. In it, competence and expertise can no longer be described as the skills of one individual only, but are instead the collaborative expertise of teams and networks, a socially shared cognition. Shared and distributed expertise is different from the traditional model of the division of labour. For one thing there is no 'higher' management which, in principle, has a mastery of the entire problem being solved and assigns various steps to be carried out by different experts; rather, the networking of expertise takes place without any such hierarchical organisation. In addition, networks of expertise often centre on projects. They emerge quickly for the purpose of solving some particular problem, and once the project is over they dismantle. For individuals, the essential skill is the ability to create quickly and spontaneously reciprocal co-operation and communication relationships between experts who represent different types of expertise. For organisations, the essential skill is to be able to create and use the various cognitive 'tools' needed in group problem solving. One such tool, for example, is a body of network-based flexible applications that support communication and the collaborative memory of an organisation or a network.

Thirdly, successful work in an environment based on information networks and increasingly globalised information sources require new kinds of information technology and communication skills, along with the intellectual capacity to control them. For example, it is only data that moves in information networks. Only once data becomes organised does it turn into information. Information only becomes knowledge and wisdom through the interpreting process of a person with expertise. Network technology creates enormous possibilities but demands high levels of skill from its users. The issue is not just technical mastery of network use, but above all the cognitive skills of presenting and developing meaningful questions, and interpreting information by integrating it with previously accumulated knowledge and giving it an appropriate context. One must also be able to critically assess the reliability and relevance of information. Because of these severe demands, the development of information networks may actually lead to the un-democratisation of the acquisition of meaningful information, unless education and training can assure not only sufficient technical skills but also especially the cognitive skills necessary for using information sources. By these skills we mean both the skills needed for processing and evaluating information as well as a well-organised foundation of prior knowledge.

Fourthly, since networks enable rapid interaction between people representing various cultures and professions or people and organisations previously unknown to each other, the challenges of reciprocity and understanding others become even more complex. Network-based operating practices are not just about possessing the skills to use information technology hardware and media, but of possessing more general skills of co-operation, information processing and communication. The essential element in these skills is ensuring that the information acquired through the networks be understood and transferred (by all parties) into usable knowledge by connecting it to meaningful contexts.

A widely experienced concern is how it will be possible prepare future generations to cope with all these cognitive, social, and motivational challenges of the emerging knowledge-based society. In many national and international strategies attention has been directed towards the use of ICT in teaching and studying. The rapid development of ICT has provided education with a rich variety of promising tools and information services.

2. TECHNOLOGY-BASED EDUCATION: DESIRE FOR BETTER LEARNING

In the public information society discourse, the arguments for the use of ICT in education are typically based on various self-evident benefits of information and communication technology. For example, the possibilities for an interactive relationship between the learner and the system are assumed to be beneficial to learning. Similarly, it seems obvious that the multimedia features of ICT that open new possibilities to illustrate learning tasks also facilitate the understanding of the phenomena. The possibility of using ICT in simulating real-life phenomena is one of the features of this new technology that has held out hopes of its educational value. The usefulness of the ICT based simulation has been self-evident in many special training situations, as in training jet plane pilots or nuclear power plant operators. Very fast world-wide access to information sources is currently one of the most promising features of ICT that raises enthusiasm among educators. Educators also rely on the Internet as a useful tool for synchronous and asynchronous communication between teacher and students and among students.

How real are these technology-driven educational benefits of ICT? In spite of the numerous studies on the effects of ICT on teaching and learning, there is not very much specific scientific evidence supporting these 'self-evident' benefits. As a matter of fact, unambiguous evidence of the educational efficiency of the individual technical features of the ICT is unlikely. The effects of ICT depend not only on the equipment but also above all on the pedagogical implementation of technology. Thus, the pedagogical approaches used are, in many cases, more important than the technical features of the applied technology. A successful application of ICT in education always means that many systemic changes in the whole activity environment of the classrooms also take place. This has especially been stressed by Salomon (1994) who has tried to develop tools for describing and analysing these patterns of changes.

ICT has played a noteworthy role in developing new theoretical approaches on learning and instruction. One source of the desires of ICT's impact originates in the current learning research. The adaptation of constructivist epistemological principles in particular has encouraged learning scientists to analyse how technology-based environments would provide learners with new opportunities for exploratory activities which are beneficial for knowledge construction. In the present tradition of constructivism, free, spontaneous exploration and discovery have frequently been stressed. This 'romantic' interpretation of constructivism does not, however, offer an appropriate theoretical basis for designing learning environments for complex concepts and skills (Reusser 1993). Systematic guidance by the teacher is needed, but not in the form of attempts at knowledge transmission. The role of the teacher in the classroom organised on the ideas of constructivism is problematic (Cobb 1994). Thus it is a great challenge to develop constructivism-based models for indirect instructional strategies in which appropriate teacher guidance can be connected with the self-directed explorative activity of the student. Our own research on complex learning in a computer-based environment has shown that it is not an unlimited freedom to act, but a more or less guided sequence of adequate activities that is essential for successful conceptual construction in students (Lehtinen and Repo 1996; Lehtinen and Rui 1996). Experiments with so-called micro-worlds and simulation-based science learning environments (de Jong and Wouter 1998) have shown that information technology can be used in creating new forms of teacher-student interaction in which the spontaneous activity of the student and the teacher's guidance are in balance.

In some computer-based learning environments, the complexity of the content area has consciously been considered. One principle that seems to be common for different approaches is to acquaint students with the structural complexity of the tasks from the very beginning. Instead of teaching sequences of isolated content units, these environments present the students with complex problems while they are studying the sub-elements of problems (Achtenhagen et al. 1993; Lajoie and Lesgold 1992). One of the desires related to the educational use of ICT is that with the help of information technology we can develop environments which present complex problem situations and, at the same time, provide students with a rich variety of tools which effectively support students' attempts to control the complex relationships of learning tasks.

The authenticity of the learning situations and tasks is assumed to be an important factor that can facilitate higher order learning (Brown, Collins, and Duguid 1989). This idea has been particularly stressed in the work of *The Cognition and Technology Group* at Vanderbilt (1996). The basic idea is to anchor the learning of knowledge and skills to meaningful situations and activities of everyday life. This has, however, appeared to be a very difficult task within the framework of institutional education. It is very difficult to bring meaningful activities of the external world to the teaching-learning process because of the restrictions of classroom teaching. It is also typical that practical projects carried out in the school context frequently fail to improve the learning of abstract knowledge and skills. Many learning scientists have assumed that information technology can be used to mediate real life problems to schools in a form that makes it possible to connect the practical problem solving with the learning of theoretical ideas and general thinking skills.

Instructional models based on peer co-operation or collaboration have been stressed in recent research of learning and instruction (Dillenbourg 1999; Littleton and Häkkinen 1999). In order to increase the possibilities for mutual understanding and task-related social interaction, interaction tools are needed that are adequately related both to the new concepts to be learned and to the previous experience and knowledge of the students. There should be flexible methods available for the students, to help them externalise their preliminary ideas and make their thinking processes transparent to other people. The tools available in an activity environment should permit students to follow one another's thinking processes, even in situations where one is not able to argue verbally. Furthermore, the environment and the working methods should encourage students towards mutual reflection.

Even in the late eighties most experiments on computer-supported learning were based on the so-called solo-learner model, and the opportunities to individualise learning processes were supposed to be the crucial feature of computers. This was especially true for CAI-programmes based on the ideas of programmed instruction, but the emphasis of individualistic models was also typical for many learning environments designed according to the constructivist principles (Crook 1994). It was, in particular, the omission of social interaction in computer-based learning environments which worried many educators in the eighties (Cuban 1986; Turkle 1984).

During the last ten years the situation has dramatically changed. Most of the recent research on the use of information and communication technology in education is more or less explicitly considering technology's possibilities to facilitate social interaction between teacher and students and among students (Lehtinen et al. 1999; Littleton and Light 1999). There are two research traditions that have powerfully contributed to the development of the ideas of computer-supported collaborative learning. The first source is co-operative learning, which was an important element already in the programmes of progressive pedagogics from the beginning of this century. According to Slavin (1997), research on co-operative learning can be considered as one of the greatest success stories in the history of educational research.

The other source of inspiration for developing computer-supported collaborative learning originates from the research on Computer-Supported Collaborative or Co-operative Work (CSCW). This research has revealed many issues about the co-operative nature of work in computerised work context (Baskerville et al. 1995). Some of the theoretical ideas and computer tools used in CSCL environments have originally been created and elaborated in modern work contexts.

Recent research on the role of collaboration in learning has tried to find deeper theoretical frameworks that could better guide the developing of technology-aided learning environments (Dillenbourg 1999; Lehtinen et al. 1999). A distinction between co-operation and collaboration is conceptually central in this approach. The distinction is based on different ideas of the role and participation of individual members in the activity. Co-operative work is accomplished by the division of labour among participants. It is an activity where each person is responsible for a portion of the problem solving whereas collaboration involves the mutual engagement of participants in a co-ordinated effort to solve the problem together.

Crook (1996) has widely analysed how computers can facilitate collaborative learning in schools. He makes a distinction between interacting *around* and *through* computers. The first perspective stresses the use of computers as tools to facilitate face-to-face communication between student pairs or in a small group. According to Crook (1996) technology may, in these situations, be serving to support collaboration by providing students with something he calls points of shared reference. He claims that a traditional classroom situation is too thinly resourced for successful collaboration. There are not enough available anchor points at which action and attention can be co-ordinated. The capabilities of computers can be used as mediating tools that help students to focus their attention to mutually shared objects (Järvelä, Bonk, Lehtinen, and Hämäläinen, in press). In Crook's (1996) distinction, interacting through computers refers to the use of networks. Local area networks (LAN) and wide area networks (WAN) and the global version of latter (Internet) provide education with a variety of mediating tools for collaboration (email, electronic bulletin boards, conferencing systems, and specialised groupware).

Appropriate representations are important elements in any learning and construction process, but the problem of relevant external representations is highlighted when complex concepts and skills are the content of learning (de Jong and Wouter 1998). Traditional teaching models do not directly consider the relationship between representations and concepts. On the contrary, it is typical that the concrete external representation used by the teacher is considered to be the complete concept. When students are not encouraged to pay attention to the abstract concepts and operations 'behind' the concrete facts and algorithmic routines, they try to learn the subject matter by imitation and memorisation of the mechanical procedures and symbolic expressions. Representational tools should help the students to externalise their idiosyncratic and informal hypothesis and to compare this hypothesis with scientific concepts and culturally shared definitions (de Jong and Wouter 1998; Reusser 1993; Collins and Brown, 1988).

3. THE IMPACT OF ICT ON LEARNING OUTCOMES: PROMISES OF MORE EFFECTIVE LEARNING

The first attempts to assess the educational use of information technology by compiling the results of several empirical studies were made in the early 1970's (e.g. Edwards et al. 1975; Vinsonhaler and Bass 1972). The first summary articles describing the experiences of the late 1960's and early 1970's concluded that computers seemed to help in training basic skills. Even the early summaries attempted to look analytically at the effects of different ways of using computers. For example, Edwards et al. (1975) started by making an interesting and still relevant distinction between two different kinds of experimental uses of information technology in teaching: one, where educational programmes were seen as substitutes for teachers, and the other, where educational software was used as an aid or supplement to the teacher's work. Their results supported the latter approach in particular, and many later studies have very consistently come up with this same finding.

Kulik and Kulik (1987) performed a meta-analysis on the 199 studies. The results of this meta-analysis can be summarised as follows:

1. Students generally learned more in classes when they received help from computers. The average effect of computers in all 199 studies used in our meta-analyses was to raise examination scores by 0.31 standard deviations, or from the 50th to the 61st percentile.

2. Students also learned their lessons with less instructional time. The average reduction in instructional time in 28 investigations of this point was 32%.
3. Students also liked their classes more when they received computer help. The average effect of computer-based instruction in 17 studies was to raise attitude-toward-instruction scores by 0.28 standard deviations.
4. Students developed more positive attitudes towards computers when they received help from them in school. The average effect size in 17 studies on attitude toward computers was 0.33.

The results of Kulik and Kulik's (1987) very extensive meta-analysis promise quite positive results from the use of computer-aided instruction. We must note, however, that the effects summarised above were average results. As a fifth point, they note that 29 of the studies analysed came to the conclusion that computer-aided instruction had no effects that would have differed from those achieved through traditional instruction.

A few years later Kulik and Kulik (1991) updated their extensive meta-analysis by adding to it all of the effectiveness studies carried out in the late 1980's. This study also showed that cognitive achievement was improved by computer-aided instruction (effect size 0.30). Later, Kulik (1994) published a summary of 12 previous meta-analyses, which turned out to have parallel results. The effect sizes found in these summaries reached all the way up to 0.50. Such large effect sizes already signify essential improvements in learning outcomes.

Khaili and Shashaani (1994) compiled studies from the late 1980's and early 1990's where the effectiveness of computer applications in teaching had been empirically studied. These studies were very extensive and looked at many aspects of learning. Based on them, a total of 151 different effect sizes could be examined. Among these, 138 (91%) turned out to be positive and 13 (9%) negative.

More interesting than the general effectiveness results are the specific results that the authors present based on the studies they compiled. Many interesting results emerge from these samples. One of the important features that clearly emerged in the meta-analysis of Khaili and Shashaani (1994) was the duration of the experiment: effects of very short-term computer-assisted instruction remained rather minimal. A crucial increase in the effect size resulted from increasing the duration of the experiment from a few days to four to seven weeks. On the other hand, for experiments that lasted even longer, the effectiveness began to decrease again. This simply means that there is some kind of novelty effect. A new method or technique brings new interest to the learning situation, which in and of itself increases motivation and improves achievement once, after a short period of practice, people learn to work with the new system. When the new method or technique has been in use in the classroom for somewhat longer, the novelty fades and what remains is the effectiveness created by the new activities and learning processes provided by the new system. Results on the duration of the experiment show us that with more long-term teaching/learning periods the effect stabilises and no longer decrease if the duration of the experiment is extended even further. Based on these results, we might argue that in the early 1990's studies of teaching effectiveness, the effect size 'purged' of the novelty effect would have been somewhere between 0.30 and 0.40.

There are interesting differences between the results of these studies done mainly in the 1990's and those done earlier. There is a clear difference in the level of education for which effects were obtained. In the studies from the 1970's and 1980's, it seemed that the largest effect sizes were found at the elementary level and that the effectiveness decreased towards the higher levels. More recent results draw a very different picture. Relatively good results are still obtained at the elementary level; they get worse at the lower secondary level; but at the upper secondary and tertiary level they are even better than at the elementary level.

Another clear difference between the earlier and the more recent studies is related to the effects of the type of applications used. The earlier studies suggested that the greatest effects came from the use of drill and practice programmes based on the ideas of programmed instruction. The recent studies show that the effects of using these programmes are very small when compared with applications that demand more autonomous active problem solving from the learner.

We can find at least two explanations for this large change. Firstly, computer-assisted learning environments based on a more modern constructivist learning theory were developed into workable applications only towards the end of 1980's and during the 1990's. The second explanation is based on a change in the assessment of learning outcomes. The earliest studies made clear that computer-assisted instruction had the greatest effects on simple memorisation and straightforward tasks, but that the programmes were not effective in teaching higher-level cognitive processes. With the shifts of emphasis in learning theory, from the early 1990's onwards these studies have also focused more on measuring problem solving skills. This has powerfully changed our attitudes about the kinds of learning environments that produce the best learning achievements.

Khaili and Shashaani (1994) made an additional important finding. Experiments done with very small student groups have produced extraordinarily high effect sizes, while the effects shrink significantly once the group sizes in the experiments increase. This result is related to an important theme which is presently being debated among scholars studying learning environments. How can we expand methods developed in small-scale experiments to cover the entire educational system?

Computer-supported collaborative learning (CSCL) is one of the most promising innovations to improve teaching and learning with the help of modern information and communication technology. Recently Lehtinen et al. (1999) finished a large review about the principles, tools, and effect of CSCL that was based on more than 200 published papers. According to these reviews the authors were able to conclude that a technologically sophisticated collaborative learning environment, designed following cognitive principles, could provide an advanced support for distributed process of inquiry, facilitate advancement of a learning community's knowledge as well as transformation of the participants' epistemic states through a socially distributed process of inquiry. Computer-supported collaborative learning appears to engage students to participate in in-depth inquiry over substantial periods of time and to provide socially distributed cognitive resources for comprehension monitoring and other metacognitive activities.

Many researchers have shown how very different technical applications can be used to facilitate collaborative and distributed teaching and learning including special network applications for CSCL, different multimedia/hypermedia applications and experiential simulations. It is not only the features of the applied technology but also the way of implementation of the technology that support student collaboration in particular. Local area networks and the Internet provide education with a variety of mediating tools for collaboration (email, electronic bulletin boards, conferencing systems, and specialised groupware). In research literature there are descriptions of several systems especially developed for various educational purposes (Lehtinen et al. 1999).

Several empirical experiments offer evidence that the well-known CSCL environments like CSILE (Lamon et al. 1996; Scardamalia and Bereiter, 1994) and Belvedere (Shutters 1998) have proved to be helpful for higher order social interaction and subsequently for better learning in terms of deep understanding. What is still lacking is the evidence that the same results could be achieved widely in normal classrooms. It is also possible that similar positive results could be reached in classrooms carrying out the same collaborative activities without computers (Lehtinen et al. 1999).

Although hundreds of papers on CSCL have been published during the last few years, the review of Lehtinen et al. (1999) shows that there are not too many well controlled experiments that could answer the questions concerning the wider applicability of CSCL in normal classrooms and the added value of computers and networks in comparison to collaborative learning environments without technology. In their review, the authors compared 18 studies in which controlled experimental designs were used. From these 18 studies, 16 showed positive effects on different cognitive or affective learning outcomes. Most of the publications studied for this review described the systems and conditions as well as the students' conversation processes, but presented no data of the learning outcomes.

Altogether, the reviews and meta-analyses of more than 1000 experiments show that ICT students have learned more and faster than students in control groups. In these experiments ICT has also improved student motivation and social interaction. The quality of learning depended on the type of ICT application.

4. ARE THERE ANY CHANGES IN REGULAR CLASSROOMS: OBSTACLES IN USING ICT IN EDUCATION

A large evaluation study in the Finnish educational system was conducted in 1998 aimed at investigating the impact of ICT on learning and instruction (Sinko and Lehtinen 1999). In the frames of this project, the main findings of the several recent national and international evaluation studies were also summarised. These results, describing the situation in regular classrooms, gave a somewhat different view on the impact of ICT than the one we could find from the experimental studies reviewed above.

In regular schools and classrooms there were a few examples in which ICT has been applied in a very innovative way. These spontaneous (not initiated by researchers) innovative implementations of ICT were often a part of a larger development project in which several teachers had networked with each other. The case studies also gave evidence that these applications have effectively created new kinds of teaching-learning processes and opportunities for deeper learning (Sinko and Lehtinen 1999).

However, in the majority of the schools, the researchers could not find any innovative use of ICT. Rather, there were many superficial activities aimed at acquainting students with the technology without any pedagogically ambitious attempt to reorganise the teaching-learning processes. In many technologically well-equipped schools, ICT was only sporadically applied in teaching-learning processes. Evaluations of the influence of ICT on teaching practices showed that only one quarter of the teachers agreed with the opinion that communication technology has essentially changed the teaching culture in their school. In general, teachers had embraced very progressive ideas of the possibilities of using ICT in reforming instruction but they had not been able to fulfil these ideas in their teaching practice. For example, when the use of ICT was examined as a tool for co-operative and collaborative learning, a conflict was noted between principles and practices. Sixty-three percent of the teachers agreed with the principle but only 22% had implemented it in practice (Sinko and Lehtinen 1999).

Most Finnish teachers have IT at their disposal either in their own classrooms or elsewhere in the school. IT is, however, not used very intensively. On the basis of the Finnish experiences it is possible to agree with Pelgrum (1996) who, after analysing the results of international assessment studies, concluded that for a majority of students the use of information technology in teaching and learning was still of very little significance.

5. CONCLUSIONS

Experimental research studies bring forward fairly promising results concerning impact of ICT on learning and instruction. According to the large assessment studies in regular schools and classrooms this positive effect cannot, however, be found in everyday teaching practices. How can this discrepancy between the two kinds of views be explained? One possibility is to question the accuracy of the experimental evidence based on the reviews and meta-analyses. When interpreting review articles and meta-analyses we must keep in mind that they might contain errors which give an overly positive picture of the effect of using information technology in education, as Kulik and Kulik (1987) point out. Another may be that although review articles are based on a large number of published studies, it is important to remember that before a research article is published, it goes through a critical evaluation process which usually screens out articles which present ‘zero findings’. Articles that obtain results in accordance with their hypotheses have a much higher likelihood of getting published, and hence it might be possible that studies which hypothesised positive results but found none would simply not get published.

A second problem with analysing the effects of ICT on learning arises from experimental design. A new method (here, teaching with the help of ICT) is usually tried out by the most enthusiastic and committed teachers, which is not necessarily the case with the control groups. A third, often-cited potential source of over positive bias, is based on the possibility that in the experiments a great deal more effort might be put into planning the teaching that utilises information technology than into the teaching of the control group. It is possible that this planning effort alone, without the use of information technology, would bring about the effects shown (see for example, Kulik and Kulik 1987). It is therefore problematic that review studies usually look only at outcomes and pay little if any attention to investments. In many success stories described in experimental research literature there have been exceptional resources available to support the teacher in planning and fulfilling the treatment, concerning either pedagogical or technical questions. That is, however, not true in the everyday situations in regular classrooms.

The majority of teachers in the Finnish assessment study felt that their own technical skills are not good enough for effective use of ICT in their education. Even more frequently, teachers expressed that they lacked the sufficient pedagogical expertise to use ICT as a tool in their teaching. They also claimed that there is not enough technical support at their disposal when they try to apply ICT in their teaching.

It is also obvious that the pedagogical ideas used in small-scale experiments are not familiar to the regular teachers or are not easy to be adopted by them. For example, in an assessment study, Finnish teachers did not regard collaborative learning as an important application of computers although the scientific community has considered the principles of computer-supported collaborative learning highly promising for the development of future learning environments. These results are certainly partly due to the novelty of the theoretical ideas in schools, but they also indicate that the theoretical and practical principles presented by the researchers are often still too immature to be widely applied in practical educational reforms.

A school system is a complex social institution that has several significant social tasks and whose practices have developed little by little over a long period. This is why it is difficult to carry out rapid changes. It is to be assumed that the model of instruction and learning based on the extensive use of ICT presupposes such profound changes in traditional practices that the mere offering of technology to schools and the wish expressed by school administrations for its introduction do not yet ensure that purposeful practices are being developed. This observation highlights the importance of carefully analysing the presuppositions of application of technology-based instructional innovations in practical classroom situations, as well as the importance of adequate implementation and dissemination strategies.

REFERENCES

Achtenhagen, F. (1993) Learning, thinking and acting in complex economic situations. *Economia* 3 (1) 18-17.

Baskerville, R., Smithson, S., Ojelanki, N., and Degross, J. (1995) Information technology and new organisational forms: Choosing chaos over panaceas. *European Journal of Information Systems* 4 (2) 66-73.

Bereiter, C. and Scardamalia, M. (1993) *Surpassing Ourselves: An Inquiry into the Nature and Implications of Expertise.* Chicago, IL: Open Court.

Brown, J.S., Collins, A., and Duguid, P. (1989) Situated cognition and the culture of learning. *Educational Researcher* 18 (1) 32-42.

Cobb, P. (1994) Constructivism and learning. In T. Husen and T.N. Postlethwaite (eds.), *International Encyclopedia of Education.* Oxford: Pergamon.

Cognition and Technology Group at Vanderbilt (1996) Multimedia environments for enhancing learning in mathematics. In S. Vosniadou, E. De Corte and H. Mandl (eds.), *International Perspectives on Psychological Foundations of Technology-Based Learning Environments.* Hillsdale, NJ: Lawrence Erlbaum.

Collins, A. and Brown, J. S. (1988) Computer as a tool for learning through reflection. In: H. Mandl and A. Lesgold (eds.) *Learning Issues for Intelligent Tutoring Systems.* New York: Springer-Verlag.

Crook, C. (1994) *Computers and the Collaborative Experience of Learning.* London: Routledge.

Cuban, L. (1986) *Teachers and Machines.* New York: Teachers College Press.

Dillenbourg, P. (1999) Introduction; What do we mean by 'Collaborative Learning'? In P. Dillenbourg (ed.) *Collaborative learning: Cognitive and Computational Approaches.* Amsterdam: Pergamon.

Edwards, J., Norton, S, Taylor, S., Weiss, M., and Dusseldorp, R. (1975) How effective is CAI? A review of the research. *Research in Review.* 33, 147–153.

Järvelä, S., Bonk, C.J., Lehtinen, E., and Hämäläinen, S. (in press) A theoretical analysis of social interactions in computer-based learning environments: Evidence for reciprocal understandings. *Journal of Educational Computing Research.*

de Jong, T. and Wouter R. van Joolingen (1998) Scientific discovery learning with computer simulations of conceptual domains. *Review of Educational Research* 68 (2), 179-201.

Katz, S. and Lesgold, A. (1993) Collaborative problem-solving and reflection in Sherlock II. In *Proceedings of the Workshop on Collaborative Problem Solving: Theoretical frameworks and Innovative systems.* Edinburgh.

Khaili, A. and Shashaani, L. (1994) The effectiveness of computer applications: A meta-analysis. *Journal of Research on Computing in Education* 27, 48–61.

Kulik, C-L.C. and Kulik J.A. (1991) Effectiveness of computer-based instruction. An updated analysis. *Computers in Human Behaviour.* 7, 75–94.

Kulik, J.A. (1994) Meta-analytic studies of findings on computer-based instruction. In E.L. Baker and H.F. O'Neil (eds.) *Technology Assessment in Education and Training.* Hillsdale, NJ: Lawrence Erlbaum.

Kulik, J.A. and Kulik, C-L.C. (1987) Review of recent research literature on computer-based instruction. *Contemporary Educational Psychology.* 12 (3), 222–230.

Lajoie, A.P. and Lesgold, A.M. (1989) Apprenticeship training in the workplace: computer-coached practice environment as a new form of apprenticeship. *Machine-Mediated Learning.* 3, 7-28.

Lamon, M., Secules, T., Petrosino, A., Bransford, J., and Goldman, S. (1996) Schools for thought: Overview of the project and lessons learned from one of the sites. In L. Schauble and R. Glaser (eds.) *Innovations in Learning. New Environments for Education.* Mahwah, NJ: Erlbaum.

Lehtinen, E. and Rui, E. (1996) Computer supported complex learning: An environment for learning experimental methods and statistical inference. *Machine-Mediated Learning.*

Lehtinen, E. and Repo, S. (1996) Activity, social interaction and reflective abstraction: Learning advanced mathematics in a computer environment. In S. Vosniadou, E. De Corte, R. Glaser, and H. Mandl (eds.) *International Perspectives on the Design of Technology Supported Learning Environments.* Mahwah, NJ: Lawrence Erlbaum.

Lehtinen, E. , Hakkarainen, K., Lipponen, L., Rahikainen, M., and Muukkonen, H. (1999) *Computer Supported Collaborative Learning: A Review*. The J.H.G.I. Giesbers Reports on Education, No. 10. Department of Educational Sciences. University of Nijmegen.

Littleton, K. and Häkkinen, P. (1999) Learning together: Understanding the processes of computer-based collaborative learning. In P. Dillenbourg (ed.) *Collaborative Learning: Cognitive and Computational Approaches*. Amsterdam: Pergamon.

Littleton, K. and Light, P. (1999) *Learning with Computers: Analysing Productive Interaction*. London: Routledge.

Negroponte, N. (1995) *Being Digital*. New York. Vintage Books.

Pelgrum, W. J. (1996) The educational potential of new information technologies: Where are we now? In B. A. Collis (ed.) *Children and Computers in School*. Mahwah, NJ: Lawrence Erlbaum.

Reusser, K. (1993) Tutoring systems and pedagogical theory. In S. Lajoie & S. Derry (eds.) *Computers as Cognitive Tools*. Hillsdale, NJ: Lawrence Erlbaum Associates.

Rifkin, J. (1995) *The End of Work. The Decline of the Global Labour Force and the Dawn of the Post-Market Era*. New York: Putman Book.

Salomon. G. (1994) Differences in patterns: Studying computer enhanced learning environments. In S. Vosniadou, E. De Corte and H. Mandl (eds.), *Technology-Based Learning Environments: Psychological and Educational Foundations*. NATO ASI Series F: Computer and System Science, Vol. 137. Berlin: Springer.

Scardamalia, M., and Bereiter, C. (1994) Computer support for knowledge-building communities. *The Journal of the Learning Sciences*. 3, 265-283.

Suthers, D. D. (1998) *Computer aided education and training initiative*. Technical Report (12 January 1998)

Sinko, M. and Lehtinen, E. (1999) *The challenge of ICT in Finnish education*. Jyväskylä: Atena.

Slavin, R E. (1997) *Research on co-operative learning and achievement: A quarter century of research*. Paper presented at the Annual Meeting of Pedagogical Psychology, Frankfurt, September.

Tapscott, D. (1996) *The Digital Economy: Promise and Peril in the Age of Networked Intelligence*. New York. McGaw-Hill.

Vinsonhaler, J. F. and Bass, R. K. (1972) A summary of the major studies on CAI drill and practice. *Educational Technology*. 12, 29–32.

BIOGRAPHY

Erno Lehtinen is Professor of Education and Dean of the Faculty of Education at the University of Turku, Finland. In his work Erno Lehtinen has aimed at combining basic research on cognition and motivation with the practical development of diagnostic tools and learning environments. He has worked as a teacher and researcher in several universities including the Universities of Turku and Joensuu (Finland) University of Bern (Switzerland) and the Learning Research and Development Center at the University of Pittsburgh. In the mid-1980s he established The Centre for Learning Research with his colleagues at the University of Turku and in 1988, the Research and Development Center for Information Technology in Education at the University of Joensuu. He chaired an expert group carrying out a large evaluation for the Finnish Parliament on the impact of information technology on teaching and learning in Finland and currently he is a member of the research expert team in OECD planning a new large international evaluation study on effects of ICT based learning environments.