COMPUTER-SUPPORTED COLLABORATIVE LEARNING: AN APPROACH TO POWERFUL LEARNING ENVIRONMENTS

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INTRODUCTION

In the public discourse of the information society 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, which open up new possibilities for illustrating learning tasks, facilitate the understanding of the phenomena. The possibility to use 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, such as the training of jet plane pilots or nuclear power plant operators. A very fast world-wide access to information sources is currently one of the most promising features of ICT raising enthusiasm among educators. Educators also rely on the Internet as a useful tool for synchronous and asynchronous communication between the teacher and students and among students.

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 take place (Salomon, 1994). ICT has played a noteworthy role in development of new theoretical approaches on learning and instruction. The adaptation of constructivist epistemological principles has particularly encouraged learning scientists to analyse how technology-based environments would provide learners with new opportunities for activities which are beneficial for knowledge construction. ICT has played an important role in many attempts to create powerful learning environments for supporting higher order learning and the development of metacognition and self-regulation. One of the desires for the educational use of ICT is that with the help of information technology we can develop environments, that present complex problem situations while, at the same time, providing students with a rich variety of tools, which effectively support their attempts to control the complex relationships of learning tasks. (Lesgold, Lajoie, Brunzo & Eggan, 1992; Steinkuehler et al. 2002; Lehtinen, 2002).

During the early years of computer-aided instruction (CAI), the leading idea about the power of this new technology was based on the so-called solo-learner model, and the opportunities to individualise learning processes. This was supposed to be the crucial feature of computers. The desire to find methods for individualising teaching, according to the precise current level of knowledge and skills of individual students, was a strong desire in the pedagogy of the 20th century. This was especially true for CAI-programs based on the ideas of programmed instruction, but the emphasis of individualistic models was also typical of many learning environments designed according to constructivist principles (Crook, 1994). It was particularly the omission of social interaction in computer-based learning environments which worried many educators in the eighties (Hawkins, Sheingold, Gearhart & Berger, 1982; Turkle, 1984).

During the last ten to fifteen years, the situation has changed dramatically. 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. Collaboration and communication is certainly a main idea in network-based learning environments, but social interaction has also been increasingly taken into consideration in the design and implementation of systems running in separate workstations (Crook, 1994; Lehtinen et al, 1999).

Most of the recent research on the use of information and communication technology in education more or less explicitly considers technology's possibilities to facilitate social interaction between teacher and students and among students (Koschmann, 1996; Koschmann, Hall & Miyake, 2002; Kumpulainen & Wray, 2002; Lehtinen et al., 1999.) Crook (1994) 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 (1994) technology may, in these situations, serve 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 anchor points available 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 & Lehti, 1999).

Many of the current studies, however, focus on collaboration through the computer, or computer-supported collaborative learning (CSCL), facilitated by different network-based collaboration tools. When Koschmann (1996) edited his first CSCL book, the majority of the chapters still described experiments based on collaboration around computer. In the CSCL 2 book edited five years later, almost all chapters describe "collaboration through computer" experiments (Koschmann, Hall & Miyake, 2002). During the last few years there has been an explosive increase in the use of computer networks in education and training. Although all "eLearning" or virtual learning environments do not include any systematic collaboration, the ideas of CSCL are gradually increasingly applied in different practical methods of network-supported learning. Technical applications used in CSCL typically include possibilities for sharing documents and a variety of specific tools for network mediated communication. The communication tools can be based on synchronic media like chat, voice mail, one-line visualization tools, and videoconferencing or they can support asynchronous communication (Lehtinen et al., 1999).

ON THE THEORETICAL RATIONALE OF CSCL

Many different theoretical approaches have been used in developing the collaborative use of ICT in learning environments. In recent years, several researchers have tried to classify the distinct approaches in the theories and models of learning. These classifications can be used in presenting the theoretical ideas, which have had an influence on the development of CSCL. For example Sfard (1998) has made a division between two main metaphors of learning: the acquisition metaphor and the participation metaphor. The first metaphor describes learning in terms of the acquisition of something in an individual mind, and knowledge in terms of property and possession. The second approach deals with learning as becoming a participant, and with knowledge as an aspect of practice, discourse and activity (Sfard, 1998).

Hakkarainen and his colleagues (Hakkarainen, Palonen, Paavola & Lehtinen, 2002) have proposed that a third metaphor, knowledge creation, should be added to the metaphors presented by Sfard. This metaphor would include emerging theoretical approaches that refer to models of how new knowledge and skills are created in cultural practices. Prototypes of these theories are the theory of knowledge creations in organisations by Nonaka and Takeuchi (1995), the activity theory based model of expansive learning by Engeström (1987) and the knowledge building idea of Bereiter (2002; but see also Chapter ?).

When presenting the theoretical rationale for their technology based collaborative learning environment, “Fifth Dimension”, Kaptelin and Cole (2002) argued that there are two distinct, but not necessarily mutually exclusive ways to see the role of social interaction in learning. The first defines learning as an individual process that can be facilitated or inhibited by various forms of social interaction. The features of social situation and the interactions taking place between the learner and his or her collaborators are seen as a “set of external modifiers” (Kaptelin & Cole, 2002, p. 303). The second view assumes that individual learning, and interaction and activity in a social system are only two different aspect of the same phenomenon. In the literature this approach is typically called Vygotskian, based on his notion of the two steps development of new abilities. At first they emerge on a social level between people, later to be internalised by the individual. However, the basic idea of the fundamentally social nature of knowledge and abilities has been developed in many different theoretical schools, not only in the Vygotskian tradition (Valsiner & van der Veer, 2000).

Cooperative learning and technology-based learning environments

In many studies on the possibilities for making use of information technology in facilitating social interaction in learning environments, the authors have relied on the traditional ideal of cooperative learning. In these theories the focus is on the learning processes taking place in individual learners, although various models of cooperation in peer groups may have facilitated learning processes. Cooperative or group learning refers to instructional methods in which students are encouraged or required to work together on learning tasks.

Slavin (1995) has presented different theoretical perspectives aimed at explaining the achievement effects of cooperative learning. In the following review, the first two perspectives (motivational and social) are mentioned as theories of cooperative learning, while the two other (developmental, and cognitive elaboration) perspectives will be discussed as approaches belonging to the collaborative learning camp. The first two could be seen as typical theories of traditional cooperative learning that has been developed as a didactical method in more or less traditional classroom situations.

The *motivational perspective* focuses primarily on the reward or goal structures under which students operate. From a motivational perspective, cooperative incentive structures create a situation in which the only way group members can attain their own personal goals is if all the members of the group are successful. The *social cohesion perspective* is related to the motivational viewpoint. According to this approach, effects of cooperative learning on achievement are mediated by the cohesiveness of the group. This perspective also emphasises primarily motivational rather than cognitive explanations for the instructional effectiveness of cooperative learning. There is, however, an important difference. Motivational theory stresses social rewards: students help their group mates learn because it is in their own interests to do so. Social cohesion theorists, in contrast, emphasise the idea that students help their group members learn because they care about the group. The social cohesion perspective emphasises teambuilding activities in preparation for cooperative learning, as well as group self-evaluation, instead of external incentives and individual accountability. A well-known application of this theory is Aronson’s (Aronson, Blaney, Srephan, Sikes, & Snapp, 1978) “Jigsaw” method, where students concentrate on different topics in thematic groups and subsequently share their expertise in groups where students from all thematic groups come together. The theoretical idea in the Jigsaw method is to create interdependence between the group members in a way that would increase social cohesion. Johnson and Johnson (1992) have proposed a similar method, and the ideas have also been applied in the so-called Fostering Community of Learners model (FCL) developed by Brown and Campione (1996). Computer and network environments have proved to be very helpful in organising applications of Jigsaw –based methods in teaching-learning situations (Pata, Sarapuu, & Lehtinen, 2002).

From cooperation to collaboration

Cooperative learning models in their original forms have not satisfied the researchers developing new technology supported environments, mainly because they have very little to say about the quality of communication and how it is related in the knowledge construction processes. Many authors agree that it is meaningful to make a distinction between cooperation and collaboration (Dillenbourg, Baker, Blaye, & O'Malley, 1996; Roschelle & Teasley, 1995).   The distinction is based on different ideas of the role and participation of individual members in the activity. Cooperative work is accomplished by the division of labour among the participants where each person is responsible for a portion of the problem solving, whereas collaboration involves the mutual engagement of participants in a coordinated effort to solve the problem together." (Roschelle & Teasley, 1995).

Both major traditions of developmental psychology, the Vygotskyan and the Piagetian, have substantially contributed to the theory of collaborative learning. Although Vygotsky (e.g. 1934/1994) in general did not believe in the usefulness of spontaneous collaboration among children of the same age, his theoretical ideas have been widely used in later theories of collaborative learning. Particularly Vygotsky’s (1978) idea of the zone of proximal development has been useful for understanding mechanisms in collaborative learning. According to this view, collaborative activity among children promotes growth if children have developmental differences. More advanced peers are likely to be operating within one another's proximal zones of development, modelling in the collaborative group behaviours more elaborated than those, which the less advanced children could perform alone.

Piaget (1926) held that social-arbitrary knowledge -- language, values, rules, morality, and symbol systems -- can only be learned in interactions with others. Peer interaction is also important in logical-mathematical thought in disequilibrating the child's egocentric conceptualisations and in the provision of feedback to the child about the validity of logical constructions. On the basis of Piaget's theory many researchers have conducted systematic empirical investigation of how social interaction affects individual cognitive development (cf. Doise & Mugny, 1984). These researchers borrowed from the Piagetian perspective its structural framework and the major concepts, which were used to account for development. Especially the concepts of socio-cognitive conflict and the coordination of points of view (centrations) have offered a basis for further development of a theory about the role of social interaction in cognitive development (see Dillenbourg, Baker, Blaye, & O'Malley, 1996).

Cognitive research on peer interaction indicates that cognitive conflicts emerging in social interaction situations facilitate cognitive performances (Mugny & Doise, 1978; Piaget, 1980); subject pairs tend to perform better than subjects working alone. Moreover, collaboration fosters the learning process of both less and more advanced students. Doise and Mugny (1984) argued that the learning process is more progressive when children with different cognitive strategies work together and engage in conflictual interaction. This argument has also been used in supporting the use of computer-mediated collaboration in learning environments. The conversation, multiple perspectives, and arguments that arise in groups, or in networks of learners may explain why collaborative groups facilitate greater cognitive development than the same individuals would achieve when working alone

Making thinking visible

In a collaborative situation individuals have to explain their ideas and conceptions to others, and through this externalisation process they also have to construct a better mental model about the issue or concept in question. These can be subsequently elaborated further by collaborators. Explaining problems to oneself fosters cognitive achievements. Hatano and Inagaki (1992) have argued that deep conceptual understanding is fostered through explaining a problem to other learners. In order to explain one's view to one's peers, an individual student has to cognitively commit him or herself to some ideas, to explicate beliefs, and also to organise and reorganise existingknowledge (Hatano & Inagaki, 1992).

The cognitive value of externalisation in social interaction is based on a process of making internal processes of thought visible (Collins & Brown, 1988: Collins, Brown, & Holum, 1991; Lehtinen & Rui, 1996; Lesgold, 1998). From a cognitive point of view, it is particularly important to transform internal and hidden processes into a public form in which they can be examined and imitated. The well known Reciprocal Teaching model, developed by Palincsar and Brown (1984), can also be considered as an example of a model in which externalisation of individual student's mental processes is essential for the advancement of metacognitive skills. According to this approach students are taught to formulate questions about a text for one another. Students have to process the material themselves and learn how to focus on the essential elements of the reading passages before they are able to do comprehension modelling. Many empirical studies have provided evidence about the effects of reciprocal teaching (Järvelä, 1996).

Computer environments can be used as tools to make the thinking processes visible in many different ways. The written communication within a learning platform makes the conversation history visible, and so can have a strong effect on the collaborative processes. Many applications, however, go further and try to externalise and make visible, for example, steps and qualitatively different contributions in the inquiry process (Hewitt, 2002; Scardamalia & Bereiter, 1994), decision making paths (e.g. Lehtinen & Rui, 1996), and argumentation structures (Suthers, Erdosne Toth, & Weiner, 1997). Pea (1994) argued that through computer-supported collaborative transformative communication, a type of learning facilitating new ways of thinking and inquiring in education could be fostered. It seems that for the purposes of transformative communication, written communication combined with face-to-face communication is more effective than face-to-face communication alone, because it requires more extensive thinking processes (Woodruff & Brett, 1993).

Learning through distributed and shared activities

Traditionally, cognitive theories have examined learning as an individual and mental process. As a consequence, cognitive theories have focused on analysing how an individual agent processes mental representations. Scientific thinking has traditionally been seen as a characteristic of an individual mind. However, in explaining human intelligent activity, both cognitive theory and the current philosophy of science increasingly emphasise the socially distributed (or shared) nature of cognition (cf., Hakkarainen, Palonen, Paavola & Lehtinen, 2002; Hutchins, 1995; Pea, 1993; Perkins, 1993; Resnick, Säljö, Pontecorvo & Burge 1997). Distributed cognition refers to a process in which cognitive resources are shared socially in order to extend individual cognitive resources or to accomplish something that an individual agent could not achieve alone. Human cognitive achievements are based on a process in which an agent’s cognitive processes and the objects and constraints of the world reciprocally affect each other.

Miyake (1986) and Hutchins (1995) have argued that social interaction, combined with the tools of technological culture provide new cognitive resources for human cognitive accomplishment. According to Miyake's analysis, understanding is iterative in nature, i.e. it emerges through a series of attempts to explain and understand the processes and mechanisms being investigated. In a shared problem-solving process, agents who have partial but different information about the problem in question all appear to improve their understanding through social interaction.

Miyake (1986) and Hutchins (1995) argued that the cognitive value of social interaction appears to be based on the fact that human beings cannot keep more that one complex hypothesis activated at a time. By using cognitive tools (Resnick, Säljö, Pontecorvo & Burge, 1997), multiple forms of representation, and other artifacts, learners are able to reduce the cognitive processing load and take on more complicated problems than would otherwise be possible (Pea, 1993; Salomon, Perkins, & Globerson, 1991). The complexity of problems or learning tasks has been a major cause for the development of many CSCL applications. In many technology-based collaborative learning environments, the complexity of the content area has been consciously considered. 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. The features of the technology and the intended collaboration with the help of the technology is meant to facilitate students in managing the requirements of the complex tasks (Feltovich, Spiro, Coulson & Feltovich, 1996; Lehtinen, 2002; Lehtinen & Rui, 1996).

Locating the learning in social and cultural system

In many recent studies on CSCL, the conceptual frameworks are based on a theoretical assumptions that learning is entirely located in a social and cultural system. In this frameworks learning is seen as “the process of change in social relations in which the learner is imperatively situated” (Suzuki & Kato, 2002). This theoretical approach relays on the widely used notion of “legitimate peripheral participation” developed by Lave and Wenger (1991). The emerging way to conceptualise the process of learning distances it from an individual learner and locates it in the changes taking place in the “community of practice” (Wenger, 1998). That is, learning is described in terms of participation in the practices of a community. This approach has been elaborated further especially in the working life context (see Wenger, 1998; Wenger, McDermott, & Snyder, 2002), and it has been used as the theoretical basis in many CSCL experiments (eg. Suzuki & Kato, 2002; several papers in Stahl, 2002). In many cases the practical consequences of these approaches for the design of learning environments have remained unclear. The original idea of the communities of practice and peripheral participation is based on observations in traditional and stable communities, in which some kind of apprenticeship type learning has been the dominating form for the socialization of young generations into the community. In modern educational situations, however, we deal with rapidly changing situations and it is difficult to see how traditional ideas about apprenticeship could be a sufficient basis for powerful learning environments in the future.

The rapidly changing environment is taken seriously in new forms of activity theory (Engestöm, 1987; 1999). Activity theory indicates that, in many cases, individuals, groups and organisations face new challenges and possibilities that cannot yet be conceptualised, and that interplay between practical exploration and theoretical contemplation produces innovation. Activity theory is a dynamic and systemic approach based on the analysis of the contradictions between different aspects of the activity situation, including subject, object and instruments, as well as rules, community, and the division of labour. In the research of and development of CSCL, the activity theory framework can be used as a tool to implement new teaching-learning approaches in educational organisations and for analysing the processes of computer-supported collaboration in general (see Halloran, Rogers and Scaife, 2002). In developing current forms of the activity theory approach, the main aim has been to create a solid tool to deal with organisational change. This is an important presupposition for all educational innovations, but the theoretical framework for developing concrete models and tools for computer supported collaborative learning needs more specific concepts referring to the collaborative and individual processes taking place in these learning environments.

One of the most widely used concepts in the CSCL literature is the notion of knowledge building, a concept originally introduced by Scardamalia and Bereiter (1989, but also see Chapter ?). With this concept they aimed at emphasizing the process of producing externally visibly “knowledge objects”, such as scientific concepts and theories. Hakkarainen and his collaborators have developed a so called “progressive inquire” model of computer supported learning, in which they present a detailed description of the steps or elements of a research like process in a school environment (Hakkarainen, Lipponen & Järvelä, 2002). This model is based partly on Bereiter’s knowledge building approach, but is elaborated further by using the dynamic and pragmatic conceptions of inquiry emphasized in the philosophy of science. The progressive inquiry model includes the following subtasks: (a) creating the context, (b) setting up research questions, (c) constructing working theories, (d) critical evaluation, (e) searching deepening knowledge, (f) generating subordinate questions and (g) constructing new working theories. These steps can be fulfilled in a flexible order and repeated several times. During all these phases the ideas should be shared among the peer group by using a suitable network-based platform supporting collaboration (Hakkarainen, Lipponen & Järvelä, 2002).

Interpersonal links, social grounding and shared regulation in CSCL

The ability to understand other participants thinking and their interpretative framework is particularly important in CSCL environments. Very often developers of learning environments presuppose that any social interaction between learners is helpful to learning. This belief is, however, not so self-evident in technologically rich classrooms, and problems of mutual understanding come to a head in various network-based virtual environments. The teaching-learning process is a complex social situation containing multiple actors, each with his or her own intentions and interpretations that influence one another's knowledge, opinions and values. For such a process to be successful, the players must participate in the construction of joint cognitive products, which requires shared understanding based on a common focus and shared presuppositions. (Järvelä, Bonk, Lehtinen, & Lehti, 1999)

In our own work, we have made use of the analysis of the strength of the ties between the collaborators. The distinction between weak and strong ties has proved to be helpful in analysis about the communication and collaboration in organisations and networks (Hakkarainen, Palonen, Paavola & Lehtinen, 2002; see also Granovetter, 1973; Hansen, 1999). Table 1 presents a summary of characteristics of knowledge exchange associated with weak and strong ties.

Table 1. Nature of Knowledge Exchange and the Strength of Ties

CHARACTERISTIC OF KNOWLEDGE EXCHANGE	**THE STRENGTH OF TIES**	
	Strong	**Weak**
Information flow	Redundant and reciprocal	Nonredundant and often asymmetric
The nature of knowledge exchanged	Usually complex	Simple or well-defined
Form of knowledge	Often noncodified or tacit	Often codified and transferable
Relation to knowledge environment	Context-bound, i.e., a part of a larger knowledge structure	Often context-free and independently understandable
Type of communication	“Thick”, including chunks, expert terms, and scripts	“Thin” and widely understandable
Management of network	Usually takes up a lot of	Not so much resources

connections	resources	needed

Strong ties typically exist between people who have a long history of joint collaboration history. The bi-directionality of strong ties is important for assimilating non-codified knowledge because the recipient is not likely to acquire the knowledge completely during the first interaction, but needs multiple opportunities to assimilate it. Problems of assimilation can be overcome only through creating strong links between the actors in question.

So called eLearning and virtual distance-learning approaches have paid only little attention to the strength of the ties between the participants. The basic weakness of virtual learning – as commonly considered – is that there is too much talk about information and knowledge delivery, and little or no discussion about the role of social communities in learning and knowledge creation (Brown & Duguid, 1999). Mere network-based contact between the learners can hardly create truly strong ties among the participants. Effective methods supporting social grounding (Dillenbourg & Traum, 1999; Mäkitalo, Häkkinen, Salo & Järvelä, 2002) could however move the participants of a virtual learning environment from weak links towards moderate ties, indicating interpersonal relations, which will already include some common experience, perspective taking and mutual understanding.

The problem of mutual understanding has been an important topic in developing CSCL applications (Järvelä, Bonk, Lehtinen, & Lehti, 1999) and has been studied from many different perspectives based on traditional theoretical ideas, including for example the notions of social formation of self (Mead 1934), social perspective taking in which individual persons points of view are related and coordinated with one another (Selman 1980), or mutual commitment in the use of language (Nystrand, 1986). Dillenbourg and his collaborator (Dillenbourg & Traum, 1999; Baker, Hansen, Joiner & Traum, 1999) have stressed the problem of shared understanding in technology-based environments by introducing the concept of social grounding in the CSCL research. Dillenbourg and Traum (1999) define social grounding as a mechanism by which two participants in a discussion try to elaborate the mutual belief that their partner has understood what they meant, to a level or criterion sufficient for the purpose of the activity.

Thousands of studies have shown that self-regulation and metacognition are important preconditions for high level learning. The research on learning related regulative processes has almost merely focused on individuals' behavior and learning (Vauras, Iiskala, Kajamies, Kinnunen & Lehtinen, in press). In the Vygotskian tradition, the development of these processes is described as a social process of guided participation between an adult and a child in which the learner internalizes and transfers the "other-regulation" to self-regulation (Rogoff, 1990; Wertsch, 1978). In this asymmetric interaction, it is the adult (or more advanced partner) who regulates and monitors the process. In peer interaction, however, the situation is more equal and it is not so clear who is the agent of the regulation of the process.

In a well-developed peer collaboration, there is a special kind of reciprocity and interdependence between the participants and even the thinking processes seem to be transactive in nature (King, 1998). This kind of (face-to-face) discussion is based on jointly shared but unconscious meta-communicative rules or contracts, which makes it possible for the collaborator to construct and maintain a shared conception of the problem (see Roschelle & Teasley, 1995). When the joint problem solving face difficult obstacles or when the communication takes place in a virtual environment, more conscious regulation is needed. In the literature there are few attempts systematically to focus on the shared regulation and metacognition in technology based collaborative learning environments (Vauras et al., 2002).

EMPIRICAL EVIDENCE OF THE EFFECTS OF CSCL

According to Salomon (1995), the possibility of intellectual partnerships with both peers and advanced information technology has changed the criteria for what is counted to be the effects of technology. Instead of only concentrating on the amount and quality of learning outcomes, we need to distinguish between two kinds of effects: "effects with a tool and/or collaborating peers, and effects of these." Salomon used the term "effects with" to describe the changes that take place while one is engaged in intellectual partnership with peers or with a computer tool including for example the changed quality of problem solving in a team. By "effects of" he means those more lasting changes that take place when computer-enhanced collaboration teaches students to ask more exact and explicit questions even when not using that system.

A traditional approach to deal with the impact of effectiveness of new instructional methods is to compare the achievements of students in traditional and experimental environments. Thousands of experimental studies on the educational impact of ICT have been carried out since the first attempts to assess the educational use of information technology in the early 1970's. These results have been summarised in dozens of review articles and meta-analyses. Our overviews of these reviews, covering more than 1000 original experiments, allowed some general conclusions to be drawn (Lehtinen, Sinko & Hakkarainen, 2001). In summary, the reviews and meta-analyses of the experiments showed that ICT students learned more and faster than students in control groups, and also showed improved motivation and social interaction.

In their review, Whelan and Plass (2002) summarised the results of more than 300 articles on network-based learning published from 1993 to 2001. Their main conclusion was that there are very few real experimental studies comparing learning outcomes in between network based and traditional educational situations. In our own review (Lehtinen et al., 1999) we also found that in most of the studies on CSCL the authors described the tools they used, the working processes, and students' attitudes but there was very seldom any rigorous experimental evidence about the effects of these learning environments.

In older studies, the experimental comparisons of achievement effects were more frequent. For example, Rysavy and Sales (1991) published a review in which they summarised the results of 13 studies on cooperative computer-based instruction (published between 1982 and 1988). In six studies, the computer-based cooperative condition resulted in better learning results than in the control conditions, whereas in four studies there were no significant differences. In the study of Hooper and

Hannafin (1988), the achievement measures were also related to different ability groupings. According to their results, the achievement of low ability students was higher in heterogeneous groups than in homogenous groups.

In their review, Lehtinen et al. (1999) summarized results from over 50 empirical studies on CSCL. They found some experimental evidence that collaboration facilitated with information and communication technology had improved student learning. For example some empirical experiments offer evidence that the well-known CSCL environments like CSILE and Belvedere have proved to be helpful for higher order social interaction and, subsequently, for better learning in terms of deep understanding (Scardamalia, Bereiter, & Lamon, 1994; Suthers, 1998). Many of the successful studies were, however, short-term experiments using very small experimental groups. This conclusion was also reached in a very recent meta-analysis (Cavanaugh, 2001) which summarized the effects of technology-based distance education in 19 empirical studies which included CSCL features. In addition Cavanaugh found that studies in which interactive technology was used as a supplementary methods, linked to face-to-face teaching, resulted in positive achievement effects. These results support the above-mentioned theoretical assumptions about the importance of strong ties and social grounding for high level learning.

In the proceedings of the last three conferences on Computer Supported Collaborative Learning (Hoadley & Roshelle, 1999; Dillenbourg, Eurelings & Hakkarainen, 2001; Stahl, 2002), there were only a few papers aimed at presenting experimental evidence about the effects of CSCL on academic achievement. This may indicate that the

CSCL research community at least partly agrees with Koschmann (1996) who argued that CSCL represent, not only a new way to use technology in education, but a completely new paradigm which also differs from the older educational technology paradigms in terms of the research methods adopted. According to this paradigm, CSCL research is not focussed on instructional efficacy, rather it is studying instruction as enacted practice. This methodological position resembles the “effect with” approach described by Salomon (1995).

The CSCL research has been rich in different innovative research approaches that focus on the communicative and social processes in the environments. In addition to the classical psychological and education approaches, CSCL research has adopted methods from anthropology, linguistics, sociology and communication studies. Ethnographical methods and discourse analysis are very much emphasised in recent studies in order to capture the social level processes without reducing them to individual level behaviours or mental processes (see Lipponen, 2002). The studies based on discourse analysis of collaborative processes in different technology-based environments open a rich view into the interaction sequences at a collective level and into social knowledge-building processes (Koschmann, Hall & Miyake, 2002) . It is, however, very difficult to extract any generalized main findings from this rich qualitative data.

Many studies focused on discourse processes in CSCL environments report increased activity of collaboration and improved quality of students’ communication when a CSCL environment is implemented in the classroom (e.g. Hewitt, 2002). Other studies, on the other hand, have shown that the activity and the quality of students’ contributions during the collaboration, when same applications are used, can vary strongly in different classrooms (e.g. Hakkarainen, Lipponen & Järvelä, 2002). Studies on the quality of students' argumentation strategies in network-based environments have shown controversial results. Although there are promising results in some studies (e.g. Murphy, Drabier, & Luepps, 1998), most of the research studies refer to difficulties in reaching high level argumentation in virtual environments without systematic training or scaffolding (Nussbaum et al. 2002; Marttunen & Laurinen, 2001).

Besides these qualitative methodological approaches some researchers have tried to describe the social level phenomena of collaborative learning processes by using social network analysis methods (Nurmela, Lehtinen & Palonen, 1999; Cho, Stefanone & Gay, 2002) and other quantitative analyses describing the relations between communicative acts (e.g. Beck, Brown, Marshall, & Schawarz, 2002). These methods have proved to be useful for describing large amounts of information about the interaction processes in a compact and illustrative way. The results of social network studies clearly demonstrate the unequal participation in CSCL processes and the differentiated roles of different participants. Because of the opportunities to present the network analysis data in a various visual representations, these methods can also be used as tools to give feedback for teachers and students during the collaborative learning processes.

CONCLUSIONS

In the early years of CSCL research, authors such as Salomon (1995) and Koschmann (1996) proposed that research on collaborative use of technical tools in learning environments cannot be characterized as a gradual extension of the tradition of learning environment research but rather by a deeper change of the theoretical and methodological thinking.

The contributions of CSCL researchers during last ten years have clearly confirmed this assumption. Computer Supported Collaborative research has been very rich both in terms of theory development and methodological approaches. The theoretical work done in this tradition can have a remarkable influence for the development of powerful learning environments in the future. There is however no unified theory underlying the different applications but the field is divided into many parallel and partly conflicting theoretical schools. A fundamental aspect of scientific activity is the attempt to find or create coherent conceptual systems that highlight and label a group of phenomena in the world to be instances in a distinct conceptual category. The borderlines of the categories are often problematic and subject to continuous debate between different theoretical schools. This is true especially in social sciences, where the content of many frequently used concepts is continuously changing. The concept of learning is an example of the kind of phenomena which are difficult to define in an exact way. This is one of the reasons for the weak accumulation of knowledge in the field of learning and instruction.

There are two seemingly contradictory problems in the current traditions of learning research. Because of the overemphasized boundaries between theoretical schools, we have not been able to maximally make use of the cumulated results of learning research and because of insufficient analyses of the fundamental ontological differences in different theories, many attempts to combine them have led to unfruitful, eclectic models. In the field of CSCL research, it is hardly possible to create a single coherent theory, which could adequately describe all the varying forms of learning. On the contrary, it seems to be necessary to create a coordinated combination of different theoretical approaches of collaborative learning, which take into consideration the specific features of the learning tasks, while at the same time locating them in their specific historical, cultural, organizational, and physical contexts.

Reviews of experiments on network-based collaborative learning show some positive learning effects when CSCL systems have been applied in classroom learning in connection to face-to-face learning situations. Experiences in pure virtual environments seem to be more problematic. Most of the studies are, however, rather limited in terms of the duration of the experiment, the number of participants, and the share of the curriculum covered. During the last few years, empirical studies on CSCL have, however, become distanced from the traditional experimental model of dealing with the effectiveness of the environment. Instead, the research community has produced hundreds of very detailed qualitative analyses of collaborative processes by using content analysis, ethnographic approaches and discourse analysis, as well as social network analysis. Due to the theoretical work and the qualitative analysis of the collaborative processes in different technology enriched environments, the developers of learning environments have obtained detailed information about possible and typical processes of collaboration mediated with the different artefacts. The approaches used in developing CSCL tools and models as well as the CSCL research from the last few years provide us with novel ideas and empirically proofed information base, which can be made use in developing powerful learning environments for different educational purposes. This information is, however, useful only if the learning environment developer is able to reinterpret it in the cultural context in question and situate it within the frames of the actual activity systems.

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