The evolution of research on computer-supported collaborative learning: from design to orchestration

8 authors, including:


Pierre Dillenbourg
École Polytechnique Fédérale de Lausanne
329 PUBLICATIONS **8,205** CITATIONS


Sanna Järvelä
University of Oulu
139 PUBLICATIONS **2,848** CITATIONS

Sten Ludvigsen
University of Oslo
63 PUBLICATIONS **782** CITATIONS

Sally Barnes
University of Bristol
10 PUBLICATIONS **576** CITATIONS

Chapter 1

THE EVOLUTION OF RESEARCH ON COMPUTER-SUPPORTED COLLABORATIVE LEARNING

From design to orchestration

Pierre Dillenbourg[1], Sanna Järvelä[2], and Frank Fischer[3]
[1]Ecole Polytechnique Fédérale de Lausanne, Switzerland, [2]University of Oulu, Finland, [3]Ludwig-Maximilians-Universität München, Germany.

Abstract: This chapter summarizes two decades of research on computer-supported collaborative learning (CSCL). We first review the key idea that has emerged, namely the fact that collaboration among peers can be ‘designed’, that is, directly or indirectly shaped by the CSCL environment. Second, we stress the fact that affective and motivational aspects that influence collaborative learning have been neglected by experimental CSCL researchers. Finally, we point out the emergence of a new trend or new challenge: integration of CSCL activities into larger pedagogical scenarios that include multiple activities and must be orchestrated in real time by the teacher.

Key words: Learning technologies, collaborative learning, collaboration scripts, technology-enhanced learning, shared knowledge, motivation, self-regulation

1. INTRODUCTION

Collaborative learning describes a variety of educational practices in which interactions among peers constitute the most important factor in learning, although without excluding other factors such as the learning material and interactions with teachers. The term ‘computer-supported’ refers not only to connecting remote students but also to using technologies to shape face-to-face interactions. Collaborative learning is used across all age levels of formal schooling, from children doing handicrafts together to teams of university students carrying out a project. In life-long education, collaborative learning is a key paradigm in informal learning (e.g., sharing knowledge among communities of practices) but has been somewhat underutilized in corporate training.

The evolution of research on computer-supported collaborative learning (CSCL) can be depicted as being divided into three ages (Dillenbourg & Fischer, 2007). In the first age (1990-1995), CSCL emerges after the neglect of collaborative learning in educational technology for more than 20 years. These first years led to the understandings (1) that collaborative learning results from the effort necessary for co-construction of a shared understanding of the field, and (2) that productive social interactions can be engineered by careful design of CSCL environments. The second age (1995-2005) is characterized by the growth of a scientific community (it acquired its own conference cycle, book series, society and journal). This community developed some engineering expertise for the whole life cycle of social interactions: the design of environments and activities, their real time analysis and their later utilization by the environment. The third age (since 2005) will probably be characterized by the disappearance of CSCL as a distinct pedagogical approach. Instead, collaborative activities are becoming integrated within comprehensive environments that include non-collaborative activities stretching over the digital and physical spaces and in which the teacher orchestrates multiple activities with multiple tools. We set these three ages at 5, 10, and 5 years respectively, but of course there are no clear cut ends or beginnings.

The second section of this chapter summarizes the ideas that emerged in the first and second ages. CSCL actually covers a broad range of scales. For instance, on the 'small scale' end of the continuum we find studies of a group of two students working for 30 minutes in a rich synchronous environment. CSCL is not restricted to on-line remote collaboration and includes many studies of collaboration among students sitting in front of the same computer. On the 'large scale' end, we find studies of a community of several thousand members who interact asynchronously on-line over several years to develop a piece of software or an encyclopedia, for instance. Naturally, socio-cognitive theories of learning have had more influence on the small scale end while socio-cultural theories have been more present at the other end of the scale. At the methodological level, quantitative experimental methods were more often used in research on small scale CSCL while qualitative ethnographic methods were applied at the large scale end. However, this distinction is not clear cut, as understanding how peers co-construct meaning is a challenge that pervades all levels. Many studies combine quantitative and qualitative methods. While this chapter is slanted towards the small scale end, another chapter in this book leans more toward the large scale end (Lahn & Sutherland, this volume).

The third section of this chapter reviews a whole dimension of collaborative learning that has been neglected in CSCL, namely the affective and the motivational factors.

The fourth section describes the third age of CSCL with the shift in focus toward the integration of CSCL activities into more comprehensive pedagogical activities. This section also sets up some research issues for future work in this community.

This chapter reviews contributions from the whole CSCL community, in which the Kaleidoscope Network of Excellence members have been very active, but does not discriminate their specific contribution.

2. CSCL IN A NUTSHELL

The field of CSCL produced a complex set of models, ideas and results that we artificially divide into 10 points for the sake of clarity.

1. *More interaction balances out less individualisation.* Nowadays, group learning with computers is so widespread that one can hardly imagine that this was not the case a few years ago. Actually, following the introduction of computers in education, the key educational principle was rather the adaptation of instruction to individual needs. Nonetheless, it appeared that when we did have to put two children in front of a computer, the results were actually positive: the imperfect individualisation was compensated for by the benefits of social interactions (Dickson & Vereen, 1983). The focus moved progressively from learner-system interactions to social interactions. The emergence of CSCL reflects both the evolution of learning theories, namely situated and distributed cognition (see point 2), and also technological evolution. Nowadays, almost any laptop comes by default with three built-in networking possibilities (LAN, WiFi and Bluetooth). We live in a networked world. The notion of adaptation to users is still of interest for CSCL research but is applied nowadays to a variety of group situations.
2. *There is an illusion of convergence.* CSCL practices lie at the crossroads of two different perspectives. From an instructional and educational psychology perspective, activities that foster social interactions are methods by which individuals construct knowledge. Within a socio-cultural perspective, social interaction is more than a method, it is the essence of cognition and hence the goal of learning. These approaches may be compatible at the practical level but induce confusion at the theoretical level: one may develop collaborative learning methods for enhancing individual learning without necessarily viewing cognition as a social process. More precisely, some scholars in CSCL consider social

cognition as an extension of individual cognition, as in Perkins' concept of person-plus, while pure socio-cultural scholars view cognition as intrinsically social and thinking as a dialogic activity (Wegerif, 2007). While both perspectives have been represented within Kaleidoscope, the authors of this synthesis are closer to the instructional than to the socio-cultural pole, while the opposite is true for Lahn and Sutherland (this volume).

3. *The formal/informal border is blurred*. One specific feature of CSCL has been its relevance for both formal and informal learning, without separating these two worlds hermetically. Empirical studies investigated not only informal learning that emerges in communities of practice but also attempts to transfer successful practices into classrooms, by transforming schools into learning communities (Bielaczyk & Collins, 1999; Scardamalia & Bereiter, 1994).
4. *Collaborative learning is not a recipe.* A majority of empirical studies show a significant advantage for collaborative over individual learning but other studies report no significant difference or even negative effects (Johnson & Johnson, 1999). Collaboration per se does not produce learning outcomes; its results depend upon the extent to which groups actually engage in productive interactions. As illustrated in Figure 1-1, CSCL research not only raises the global question "(1) Under which conditions is a CSCL environment effective?" but splits it into two sub-questions: (2a) "Under which conditions do specific interactions occur?" and (2b) "Which interactions are predictive of learning outcomes" (Dillenbourg, Baker, Blaye, & O'Malley, 1996). All research on learning tries to understand main effects by zooming on process variables but this phenomenon is more salient in CSCL, possibly because social interactions are easier to observe than cognitive process. Three main categories of interactions have been found to facilitate learning: explanation, argumentation/negotiation and mutual regulation. The key consequence is not at the methodology level but at the design level: the purpose of a CSCL environment is not simply to enable collaboration across distance but *to create conditions in which effective group interactions are expected to occur*.
5. *Media effectiveness is a myth.* Each time a new medium enters the educational sphere, it generates over-expectations with respect to its intrinsic effects on learning. The myth of media effectiveness has been less salient within CSCL research, perhaps because CSCL tools have produced very controversial results. The best example is the use of online asynchronous communication tools (forums): positive learning outcomes were found under certain conditions (e.g., Schellens & Valcke, 2005) but in many studies students posted so few messages that no learning could

be expected (Hammond, 1999; Goodyear, Jones, Asensio, Hodgson, & Steeples, 2004). Nonetheless, a myth never dies and signs of its survival

For this figure see the attached file

Figure 1-1. Research questions in CSCL

occur periodically in CSCL when new artefacts (PDAs, mobile phones) or new tools (WIKIS, Blogs, etc.) emerge.

6. *What matters is the effort required to construct shared knowledge.* A key question that has driven CSCL research is: How do learners build a shared understanding of the task to be accomplished? Roschelle and Teasley (1995) defined collaborative learning as the co-construction of shared understanding. Therefore, the CSCL community paid attention to the psycholinguistic concept of ‘grounding’ (Clark & Brennan, 1991) which refers to the mechanisms by which two interlocutors detect whether their partner has understood what they meant and repair eventual misunderstandings. A theoretical gap nonetheless remains, because grounding mechanisms have mostly been studied at the language level while CSCL needs to understand how they bear on the underlying knowledge level. The notion of shared understanding should not be taken simplistically. Peers never build a fully shared understanding. The actual degree of sharedness depends upon the task (this has been called the grounding criterion by Clark & Brennan, 1991). Through phases of convergence, pairs find out new differences of viewpoint that they may need to overcome, and so forth. Although students quickly adapt mutually in interaction, they share surprisingly little knowledge after collaboration (Fischer & Mandl, 2005; Jeong & Chi, 2007). During this cycle of divergence/convergence phases, what matters is not only the final result but also the intensity of the interactions required for detecting and repairing misunderstandings, what Schwartz (1995) conceptualized as the effort towards shared understanding. CSCL methods, such as the JIGSAW and ARGUEGRAPH scripts (see Weinberger, Kollar, Dimitriadis, Mäkitalo-Siegl, & Fischer, this volume), increase the initial divergence among students and hence increase the effort necessary to build a joint solution. CSCL environments combine convergence and divergence functionalities such as providing learners with both shared graphical representations and the visual identification of individual contributions or viewpoints (namely in so-called awareness tools).
7. *A greater resemblance to face-to-face interactions is not necessarily better.* The imitation bias (Hollan & Stornetta, 1992) is the belief that the more a medium resembles face-to-face interactions, the better. As a corollary, media richness is erroneously considered to predict effectiveness, despite empirical counter-evidence. For instance video-supported collaborative work is not necessarily better than audio-only situations (Anderson, Smallwood, MacDonald, Mullin, Fleming & O'Malley, 2000; Fussel, Kraut, & Siegel, 2000; Olson, Olson, & Meader; 1995). The consequence of this myth is not simply that it generates

unfounded expectations, but also that it leads to the neglect of some technology benefits. The CSCL question is no longer “how to compensate for not being face-to-face” but rather “how technology can fulfil collaborative functionalities that are not available in face-to-face situations”, for instance by maintaining links between the verbal utterances in a chat and the graphical object referred to in a shared space (Haake, 2006). These new features apply both to computer-mediated communication (making it different from face-to-face) but also for ‘augmenting’ face-to-face collaboration (Dillenbourg, 2005) in the same sense as ‘augmented reality’.

8. *Task representations mediate verbal interactions.* Should the design of educational software be different if we know there will be two users in front of the machine? Early insights came from the previously reported work of Roschelle and Teasley (1995) based on a physics microworld that was “designed for conversations”. Another prominent example is the graphical argumentation tool Belvedere that provides students with some argumentation grammar (Suthers, Weiner, Connelly, & Paolucci, 1995). The way representations shape social interaction is referred to by Suthers and Hundhausen (2003) as “representational guidance”. As postulated for various cognitive tools (Kuutti & Kaptelinin, 1997), these representations not only shape social interactions but, if they get internalized, also shape the way students reason about the domain.
9. *Structuring communication is a subtle compromise.* Semi-structured communication tools are tools that aim to scaffold productive interactions by making them easier: for instance, ‘sentence openers’ such as “Please explain why…?” are intended to trigger productive interactions (see point 3). The idea behind these tools is ‘flexible structuring’, which means that students have the freedom to use or not use the available communicative widgets. The effects of these tools on learning outcomes are rather poor (e.g., Baker & Lund, 1997) compared to somewhat more proactive conversation micro-scripts. For instance, a micro-script will prompt a student to provide counter-evidence to her peer’s previous statement (Weinberger, Ertl, Fischer, & Mandl, 2005). We call them micro-scripts to discriminate them from pedagogical methods, called collaboration scripts or macro-scripts (O'Donnell & Dansereau, 1992): these are pedagogical scenarios that structure collaboration by defining a sequence of activities and assigning roles to individual learners. While micro-scripts stimulate and scaffold argumentation with prompts, macro-scripts may for, instance, collect opinions of students (on-line) and automatically pair students with conflicting opinions. (Dillenbourg & Jermann, 2007). The triangular relationship depicted in Figure 1-1 is used here for reverse engineering: a script scaffolds the emergence of interaction patterns (2a)

which have been shown (2b) to predict the cognitive outcomes of collaborative learning. For both micro- and macro-scripts, the right level of scaffolding is a subtle compromise between the need for structuring and the risk of over-scripting (Dillenbourg, 2002). Depending on the learners' internal (cognitive) scripts for how to communicate and collaborate effectively in a learning situation, external (instructional) scripts can allow more or fewer degrees of freedom (Kollar, Fischer, & Hesse, 2006). The effects of scripts are further developed in another chapter in this volume (Weinberger et al., in this volume).

10. *Interaction analysis can be partly automated.* Because verbal interactions are the key to collaborative learning, the analysis of interactions is at the heart of CSCL. The degree of processing of these interactions varies from mirroring to guiding (Jermann, Soller, & Muhlenbrock, 2001). Mirroring simply consists of providing the learners with a visualization of their interactions. Social interactions constitute a new raw substance from which designers may create various forms of functional or artistic representations: for instance, the Sputnik environment displays the ratio of actions and dialogues for each peer and for the pair while the 'Reflect table' embeds a matrix of LEDs that displays the conversation patterns around the table (Dillenbourg, 2005). More complex analyses enable CSCL environments to provide feedback to groups or even to suggest changes regarding their teamwork. There is a growing body of research on interaction analysis methods relying on natural language processing that are useful for feedback and for adapting instructional support (Rosé, Wang, Arguello, Stegmann, Weinberger & Fischer, in press)., Some recently developed tools can be used to analyse arguments and counter-arguments in online discussions after training (Rosé et al., in press) and thus provide a basis for adjusting the script support provided by the system.
11. *There is a shift from personal to interpersonal computers.* As collaborative software should be different from the multi-user version of software designed for individuals (see point 8), hardware for collaboration might also differ from computers built for individual use. There is an evolution from the well-named "personal" computer to interpersonal computers (Kaplan et al., in press), that is, artifacts that are designed for use by several users. These artefacts include multi-input devices (e.g., computers with two mice), tangible objects (Ullmer & Ishii, 2000) and roomware (Prante, Streitz, & Tandler, 2004), that is, a variety of tools falling under the umbrella of 'disappearing computer' (Russell, Streitz, & Winograd, 2005) or 'ubiquitous computing' (Weiser, 1993). While the concept of a CSCL environment for several years concerned some virtual collaborative space, the technological evolution mentioned

in the previous point 11 brings back the physical world. There has been intensive research in the last decade on two axes. The first axis includes 'phidgets' and 'tangibles' (i.e., peripherals such as a brush, a sandbox, etc.) that enable more physical experience than the traditional mouse and keyboard (Greenberg & Fischett, 2001; Ishii & Ullmer, 1997), as well as the work on wearables and room ware. The second axis concerns the work on location-based technologies, such as mobile devices (phones, PDA) that can locate themselves in space (based on GPS, WiFi triangulation, RFID tags, etc.) and hence afford specific collaboration processes (Nova, Girardin, & Dillenbourg, 2005). While CSCL originated with the notion of virtual collaborative worlds, this highlights that CSCL is becoming *less virtual and more physical*.

In summary, a CSCL environment is not simply a tool to support communication among remote students but a tool used in both co-presence and distance settings for shaping verbal interactions in several ways (graphical representation, sentence openers, micro-scripts, macro-scripts, etc.) and for capturing, analyzing and mirroring these interactions in real time.

3. AFFECTIVE ISSUES IN CSCL: THE NEGLECTED ASPECT OF MOTIVATION

Research on motivation and self-regulation has traditionally focused on an individual perspective, but there is increasing interest in considering these processes at the social level. Theoretical extensions of mainstream motivational constructs, such as achievement goals or social goals, have emerged out of empirical work carried out in dynamic and collaborative learning environments characterized by new opportunities for social and interactive activities (e.g., Järvelä, Volet, & Järvenoja, 2007; Summers, 2006) as well as in self-regulation with reference to concepts such as social regulation, shared regulation or co-regulation (Hadwin, Oshige, Gress, & Winne, in press).

Recent studies have described the kind of emotional and motivational experiences students have during computer supported learning projects and have indicated that students with different socioemotional orientations interpret these novel instructional designs in ways which lead to different actual behaviours (Hickey, Moore, & Pellegrino, 2001; Järvenoja & Järvelä, 2005). These emotional and motivational experiences can also include negative affect and low motivation. Some CSCL environments may interfere with students’ willingness to engage. For example, computer-based learning may create frustration or negative attributions about one’s competence.

Students need to adjust to a new relationship with the teacher, who becomes a facilitator rather than the primary source of information (Blumenfeld, Kempler, & Krajcik, 2006). Moreover, CSCL students must be committed to collaboration, which may cause socioemotional problems if the group dynamic is not functional (Salomon & Globerson, 1989). In CSCL to date, there is limited research on motivation and self-regulated learning, but the concern for motivational aspects is rising. Researchers in the field of self-regulated learning and motivation frame motivation from multiple conceptual perspectives. Sociocultural and situated cognition theories (Anderson, Greeno, Reder, & Simon, 2000) recognized that individual motivation is also affected by social values and the context in which the learning takes place. Motivation is no longer a separate variable or a distinct factor, which can be applied to explain an individual's readiness to act or learn – but reflects the social and cultural environment (Järvelä & Volet, 2004). Hence, CSCL research should investigate motivation in new pedagogical cultures and new learning environments (e.g., Järvelä & Niemivirta, 2001).

CSCL's focus on cognitive aspects of collaboration has already been extended to include social, affective and motivational issues (Jones & Isroff, 2005). Empirical studies have shown that while members of a group may co-operate, the group itself, as a social entity, does not always reach mutually shared cognitive and social processes of collaboration. For example, Järvelä and Häkkinen (2002) analysed an asynchronous virtual pre-service teacher education course and noticed that lack of reciprocal understanding between the interacting students contributed to the low quality of the discussions. Learning through collaboration is not something that just takes place whenever learners come together. In any joint venture, team members must be committed to ongoing negotiation, and continuous update and review of progress and achievement. This involves both cognitive and motivational engagement. Social learning environments are expected to rely on smooth interactions between individuals, but at times group processes interfere with individual learning processes. Students who are required to form a group for a learning activity are expected to develop a shared goal for the joint activity (Roschelle & Teasley, 1995). Engaging in a collaborative venture means entering into an interpersonal exchange in which sustained investment in constructing shared meaning of the task is essential. Yet, in order to develop a shared meaning of the task, members of the group must commit themselves fully to the shared activity (Resnick, 1991). True collaboration with shared understanding in this sense is difficult. Conflicting views may emerge and challenge motivational and affective processes. Motivation and emotion regulation processes within socially challenging learning activities are therefore situated, social, interactive, dynamic and reciprocal in nature

(Järvelä, Volet, & Järvenoja, 2007). If group members are willing to invest their energy in shared regulation processes, then they become more closely attuned to the opportunities associated with the experience of shared understandings (Crook, 2000).

Several studies have shown how different elements, such as lack of common ground in shared problem-solving (Mäkitalo, Häkkinen, Järvelä, & Leinonen, 2002) or multiple cognitive perspectives and complex concepts (Feltovich, Spiro, Coulson, & Feltovich, 1996), can inhibit collaborative knowledge construction. These situations are also often,socio-emotionally challenging and such challenges can act as obstacles to motivated action. The regulation of motivation and emotion at both the individual and group level is critical for successful collaboration. Socio-emotional appraisals can compete with goal oriented action at different phases of the learning process. Hence, the regulation of emotions and motivation is needed on a continual basis until task completion (Boekaerts & Corno, 2005; Järvenoja & Järvelä, 2005).

As widely documented in the educational literature, groups can face multiple types of social challenges (e.g., Salomon & Globerson, 1989). These can range from perceived incompatibility of personality characteristics to emerging problems in social relationships. During a group activity, group members can face challenges due to differences in their respective goals, priorities and expectations, or to conflicts generated by interpersonal dynamics, such as different styles of working or communicating, the tendency for some individuals to rely on others to do their share of the work and power relationships among members (Blumenfeld, Marx, Soloway, & Krajcik, 1996; Burdett, 2003; Webb & Palincsar, 1996). Groups that are culturally diverse often face further challenges due to more substantial differences in personal background characteristics. These can include language and preferred communication style, as well asprior cultural-educational experiences which make students feel unprepared to break out of their comfort zone and interact with less familiar peers (Volet & Karabenick, 2006).

Because detailed motivational analyses are still rare in CSCL it is difficult to specify the exact motivational challenges of CSCL. Obviously, the social challenges of CSCL already identified, such as group dynamics, contribute also to students' motivation (e.g., goals, interest, emotion control) and may partly explain low engagement in CSCL. Forthcoming analyses of social processes of motivation as well as co- and shared regulation processes in CSCL (e.g., Hadwin et al., in press) will reveal more about potentials of CSCL with respect to students' motivation, for example, in terms of opening up new opportunities for sharing goals and regulating their achievement.

Effective CSCL can be considered from a self-regulated learning research perspective. Self-regulated learning is a theory which explains effective learners' cognitive and motivational engagement. Self-regulated learners take charge of their own learning by choosing and setting goals, using individual strategies in order to monitor, regulate and control different aspects which influence the learning process and evaluating their actions (Boekaerts, Pintrich, & Zeidner, 2000). CSCL models (e.g., Singer, Marx, Krajcik, & Chambers, 2000; Hakkarainen, Lipponen, & Järvelä, 2002) afford opportunities for students to engage in self-regulated learning that include encouraging students to set their own goals, emphasizing collaboration and negotiation and proving scaffolding during learning. The results of these studies have provided evidence that CSCL may create more challenging learning situations for students.

Researchers on self-regulated learning explore technologies to help students develop better learning strategies and regulate their individual and collaborative learning process as well as scaffolding their motivation and engagement (e.g., Hadwin, Winne, & Nesbit, 2005). The potential of these tools is not fully applied currently in CSCL but synergy can be seen between motivation and self-regulated learning theories, collaborative learning and instructional design, which no doubt will advance the CSCL field. Self-regulated learning tools are intended to promote motivated learning from the individual learning standpoint as well as social and interactive learning (Azevedo, 2005). Recent studies have put effort into designing computer-based scaffolds for self-regulated learning (Azevedo & Hadwin, 2005). For example, in a study within an online scientific inquiry learning environment, Manlove, Lazonder and De Jong (2005) examined the effect on students' model quality of a tool designed to support planning and monitoring. The results showed a significant correlation between planning and model quality. Winne and his colleagues (2006) have developed the gStudy software, integrated in the Learning Kit environment, which helps learners learn more effectively by enhancing self-regulated learning. The environment gathers detailed process data on students' actions that are displayed to students to enhance their awareness of their learning process. Tools in the Learning Kit are aimed at helping learners develop learning motivation and new tactics for managing individual and collaborative activities.

4. THE CHALLENGE OF ORCHESTRATION

As technologies are becoming ubiquitous, the boundary between computer-supported collaboration and other forms of collaboration is vanishing. CSCL activities occur within broader learning environments, where they are integrated with activities occurring at various social levels (e.g., individual, group, class), across different contexts (classroom, home, laboratory, field trips, etc.) and media (with or without computers, video, etc.). Fischer and Dillenbourg (2006) spoke of "orchestration" as the process of productively coordinating supportive interventions across multiple learning activities occurring at multiple social levels. The orchestration refers to two types of interplay, the interplay between different activities (e.g., how individual work is integrated in team work) but also, within the same activity, the interplay of individual affective or cognitive processes on the one hand and social processes on the other. In other words, orchestration covers different forms of coordination:

1. *Orchestrating activities at different social planes.* The so-called 'macro' scripts (see Weinberger et al., this volume) integrate activities occurring at different social levels by implementing a 'workflow', that is, a flow of data between activities. For instance, the answers produced individually in a given activity are used for forming groups in a subsequent activity and the results of this group activity are then compiled to support the teacher debriefing session (Dillenbourg & Jermann, 2007). In this case, the bureaucratic work of orchestration is off-loaded to the system, which lets the teacher devote more attention to other aspects of orchestration, such as monitoring individual or group activities, adapting deadlines or workload, etcetera.
2. *Orchestrating scaffolds at different social planes.* Tabak (2004) suggested the term synergistic scaffolding to address the design of integrated sets of coordinated and supporting interventions at different levels. Scaffolding come from many sources in a regular classroom setting: the teacher, the software, the learning material, peers. These scaffolds might develop synergies when they are part of an effective overall strategy. Conversely, if the scaffolds are not orchestrated appropriately, the potential synergy will not be realised. Even worse, scaffolds on different social planes and from different sources can interact negatively. For example, the scaffolding done by the teacher during whole class sessions might work against group scaffolding by a CSCL script. Approaches to the orchestration of scaffolding on different planes and from different sources in integrated environments are still quite general and have only just begun to stimulate more rigorous empirical research.
3. *Orchestrating self-regulation and external regulation.* Technology-supported learning groups with an appropriate level of instructional guidance are more successful than groups without this guidance (Kirschner, Sweller, & Clark, 2006). Although this statement seems quite agreed upon, it is not clear how to determine the appropriateness of

guidance. In their scripting approach, Kollar, Fischer, and Slotta (2007) suggested a distributed cognition framework in which this issue has been framed as the interplay of internal (cognitive) and external (instructional) collaboration scripts. The basic idea is that in any given collaborative learning situation, learning processes and outcomes depend critically on the availability of appropriate regulatory information (see Weinberger et al., this volume).

4. *Orchestrating individual motivation and social processes.* In section 3 of this chapter, we stressed the need to broaden CSCL research to include affective and motivational issues. Successful engagement in CSCL presumes norms that allow members to feel safe, take risks and share ideas. There is not yet much research how these individual, affective issues interact with the social processes. In a collaborative learning situation, an individual group member can play a leading role in activating motivation regulation (Järvenoja & Järvelä, 2005). Socially shared learning tasks may also stimulate new strategies for motivation regulation (Järvelä, Järvenoja, & Veermans, 2007), as well as collaborative knowledge construction and joint metacognitive regulation (Hurme, Merenluoto, Salonen, & Järvelä, 2007). Theory and practice for CSCL will be advanced when there is more synergy between motivation, self-regulated learning and collaborative learning research.
5. *Orchestration requires adaptivity or flexibility.* How to fade the external scaffolding in and out is currently a "hot" research topic (see Pea, 2004; Wecker & Fischer, 2007). If, for example, a script is intended to be internalized, the degree of external scaffolding should progressively decrease until it disappears. Tuning the degree of scaffolding can be done by the teacher or by the CSCL environment. Adaptation by the system requires automatic interaction analysis (Dönmez, Rosé, Stegmann, Weinberger, & Fischer, 2005) to model the current internal scripts of the participants and hence adapt the amount of external guidance. Adaptation by the teacher requires providing him or her both with information on the group process and with functionalities for increasing or decreasing the amount of scaffolding during classroom runs. This means that scripting environments must embed tools for visualizing on-line interactions or even propose diagnostics and let teachers change the CSCL environment in real time. Dillenbourg and Tchounikine (2007) reviewed the different parameters that teachers should be allowed to modify when they execute scripts.
6. *The teacher conducts the orchestration.* In technology-enhanced learning, the slogan "from the sage on the stage to the guide on the side" became a commonplace to stress the evolution of the teacher's role. This vision was even stronger in CSCL because the idea that students learn

from each other in some way weakens the teacher's role as knowledge provider. However, most CSCL scholars would agree that socio-constructivism does not mean 'teacherless' learning, but changes the role of the teacher to be less of a knowledge provider and more of a 'conductor' orchestrating a broad range of activities; this role is becoming a central concern in CSCL. It is a key issue for design of CSCL environments, namely with regard to providing teachers with tools to monitor group activities and adapt the environment flexibly. It has became a central issue not only in socio-cultural studies but also the experimental research on CSCL.

Investigating these various forms of orchestration raises several methodological challenges for CSCL research which cannot be elaborated fully here. Among the most important methodological challenges are:

1. *How to ensure knowledge accumulation in CSCL orchestration research when concepts and methods become increasingly heterogeneous?* As is the case for educational research more generally, CSCL research has been suffering from suboptimal knowledge accumulation because researchers do not systematically refer to a set of agreed upon concepts and methods (e.g., Arnseth & Ludvigsen, 2006). Given the call for including rather more heterogeneous concepts from different social planes and potentially from different scientific disciplines, the threat of fostering the problem of low knowledge accumulation is high. Conceptual as well as methodological convergence are among the main desiderata here (Strijbos & Fischer, 2007).
2. *How to conduct basic research given the increasing complexity of interacting factors?* There are different ways to deal with the increased complexity of orchestration research designs. For example, design research approaches typically suggest abandoning the idea of varying one or two variables in a controlled lab or field experiment, given that hundreds of variables still interact uncontrolled in a real classroom setting (e.g., Hoadley, 2004. In contrast, other researchers hold that there are possibilities of disentangling a small number of key variables on different planes (individual, group, class) that might be varied or controlled in multilevel experimental designs (Fischer, Wecker, Schrader, Gerjets, & Hesse, 2005; De Wever, Van Kerr, Schellens, & Valcke, 2007).
3. *How to create new forms of interaction of CSCL researchers and CSCL practitioners?* Because CSCL research concerns real educational contexts, it increasingly involves teachers as well as other practitioners. Realistically speaking, many forms of practitioner involvement in the research process and scientists' involvement in the process of learning

environment design are impracticable (e.g., Pellegrino & Goldman, 2002. We suggest that a primary task of orchestration research might turn out to be identification, design, and implementation of appropriate forms of interactional 'scripts' for researchers, designers, and/or teachers (Bauer & Fischer, 2007).

REFERENCES

Anderson, A. H., Smallwood, L., MacDonald, R. Mullin, J. Fleming, A. and O'Malley, C. (2000): Video Data and Video Links in Mediated Communication : What do Users value ? *International Journal of Human-Computer Studies*, **52**, 165-187

Anderson, J. R., Greeno, J. G., Reder, L. M., & Simon, H. A. (2000). Perspectives on learning, thinking, and activity. *Educational Researcher, 29*(4), 11-13.

Arnseth, H. C., & Ludvigsen, S. (2006). Systemic versus dialogic research in CSCL. *International Journal of Computer-Supported Collaborative Learning, 1*, 167-185.

Azevedo, R. (2005). Using hypermedia as a metacognitive tool for enhancing student learning? The role of self-regulated learning. *Educational Psychologist, 40*, 199-209.

Azevedo, R., & Hadwin, A. F. (2005). Scaffolding self-regulated learning and metacognition: Implications for the design of computer-based scaffolds. *Instructional Science, 33*, 367-379.

Baker, M., & Lund, K. (1997). Promoting reflective interactions in a CSCL environment. *Journal of Computer Assisted Learning, 13*, 175-193.

Bauer, K., & Fischer, F. (2007). The educational research-practice interface revisited: A scripting perspective. *Educational Research and Evaluation, 13*, 221-236.

Bielaczyc, K., & Collins, A. (1999). Learning communities in classrooms: A reconceptualization of educational practice. In C. M. Reigeluth (Ed.), *Instructional design theories and models: A new paradigm of instructional theory* (pp. 269-291). Mahwah, NJ: Erlbaum.

Blumenfeld, P., Kempler, T., & Krajcik, J. (2006). Motivation and cognitive engagement in learning environments. In K. Sawyer (Ed.), *Cambridge handbook of the learning sciences* (pp. 475 - 488). New York: Cambridge University Press.

Blumenfeld, P., Marx, R., Soloway, E., & Krajcik, J. (1996). Learning with peers: From small group cooperation to collaborative communities. *Educational Researcher, 25*(8), 37-40.

Boekaerts, M., & Corno, L. (2005). Self-regulation in the classroom: A perspective on assessment and intervention. *Applied Psychology: An International Review, 54*, 199-231.

Boekaerts, M., Pintrich, P. R., & Zeidner, M. (Eds.). (2000). *Handbook of self-regulation*. San Diego, CA: Academic Press.

Burdett, J. (2003). Making groups work: University students' perceptions. *International Education Journal, 4*, 177-191.

Clark, H. H., & Brennan, S. E. (1991). Grounding in communication. In L. B. Resnick, J. Levine & S. D. Teasley (Eds.), *Perspectives on socially shared cognition* (pp. 127-149). Washington, DC: American Psychological Association.

Crook, C. (2000). Motivation and the ecology of collaborative learning. In R. Joiner, K. Littleton, D. Faulkner, & D. Miell (Eds.), *Rethinking collaborative learning* (pp. 161-178). London: Free Association Books.

De Wever, B., Van Keer, H., Schellens, T., & Valcke, M. (2007). Applying multilevel modelling on content analysis data: Methodological issues in the study of the impact of role assignment in asynchronous discussion groups. *Learning and Instruction, 17,* 436-447.

Dickson, W. P., & Vereen, M. A. (1983). Two students at one microcomputer. *Theory into Practice, 22,* 296-300.

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

Dillenbourg, P. (2005) Designing biases that augment socio-cognitive interactions. In R. Bromme, F. Hesse & H. Spada (Eds.), *Barriers and biases in computer-mediated knowledge communication* (pp. 243-264). New York: Springer.

Dillenbourg, P., Baker, M., Blaye, A., & O'Malley, C. (1996). The evolution of research on collaborative learning. In E. Spada & P. Reimann (Eds.), *Learning in humans and machine: Towards an interdisciplinary learning science* (pp. 189-211). Oxford, United Kingdom: Elsevier.

Dillenbourg, P., & Fischer, F. (2007). Basics of computer-supported collaborative learning. *Zeitschrift für Berufs- und Wirtschaftspädagogik, 21,* 111-130.

Dillenbourg, P. & Jermann, P. (2007). Designing integrative scripts. In F. Fischer, H. Mandl, Haake & I. Kollar (Eds.), *Scripting computer supported communication of knowledge: Cognitive, computational and educational perspectives* (pp. 275-301). New York: Springer.

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

Dönmez, P., Rosé, C. P., Stegmann, K., Weinberger, A., & Fischer, F. (2005, May). *Supporting CSCL with Automatic Corpus Analysis Technology.* Paper presented at the International Conference on Computer Supported Collaborative Learning (CSCL) 2005: The Next 10 Years, Taipei, Taiwan.

Feltovich, P. J., Spiro, R. J., Coulson, R. L., & Feltovich, J. (1996). Collaboration within and among minds: Mastering complexity, individually and in groups. In T. Koschman (Ed.), *Computer systems for collaborative learning* (pp. 25-44). Hillsdale, NJ: Erlbaum.

Fischer, F., & Dillenbourg, P. (2006, April). *Challenges of orchestrating computer-supported collaborative learning.* Paper presented at the 87th. Annual Meeting of the American Educational Research Association (AERA), San Francisco, USA.

Fischer, F., & Mandl, H. (2005). Knowledge convergence in computer-supported collaborative learning - the role of external representation tools. *Journal of the Learning Sciences, 14,* 405-441.

Fischer, F., Wecker, C., Schrader, J., Gerjets, P. H., & Hesse, F. W. (2005, August). *Use-inspired basic research on the orchestration of cognition, instruction and technology in the classroom.* Paper presented at the SIG Invited Symposium "Instructional design and empirical research: Experiments and/or design experiments" at the 11th Conference of the European Association for Research on Learning and Instruction (EARLI), Nicosia, Cyprus.

Fussell, S. R., Kraut, R. E., & Siegel, J. (2000). Coordination of communication: Effects of shared visual context on collaborative work. In W. Kellogg and S. Whittaker (eds) *Proceedings of CSCW 2000* (pp. 21-30), New York, NY. ACM Press

Goodyear, P., Jones, C., Asensio, M., Hodgson, V., & Steeples, C. (2004). Undergraduate students' experiences of networked learning in UK higher education: A survey-based study. In P. Goodyear, S. Banks, V. Hodgson & D. McConnell (Eds.), *Advances in research on networked learning* (pp. 91-121). Dordrecht, The Netherlands: Kluwer Academic.

Greenberg, S., & Fitchett, C. (2001). Phidgets: easy development of physical interfaces through physical widgets. In J. Marks & E. Mynatt (Eds) *Proceedings of the 14th Annual ACM Symposium on User interface Software and Technology* (pp. 209-218). New York: ACM Press.

Haake, J. (2006, May). *Editable chat logs: A concept for seamless integration of chat conversations and documents in shared workspaces*. Paper presented at COOP 2006: 7th International Conference on the Design of Cooperative Systems, Carry-le-Rouet, France.

Hadwin, A., Oshige, M. Gress, G. Z., & Winne, P. (in press). Innovative ways for using gStudy to orchestrate and research social aspects of self-regulated learning. *Computers in Human Behavior*, doi: 10.1016/j.chb.2007.06.007.

Hadwin, A. F., Winne, P. H., & Nesbit, J. C. (2005). Roles for software technologies in advancing research and theory in educational psychology. *British Journal of Educational Psychology, 75*, 1-24.

Hakkarainen, K., Lipponen, L., & Järvelä, S. (2002). Epistemology of inquiry and computer-supported collaborative learning. In T. Koschmann, N. Miyake & R. Hall (Eds.), *CSCL2: Carrying forward the conversation* (pp.129-156). Mahwah, NJ: Erlbaum.

Hammond, M. (1999). Issues associated with participation in on line forums - the case of the communicative learner. *Education and Information Technologies, 4*, 353-367.

Hickey, D. T., Moore, A. L., & Pellegrino, J. W. (2001). The motivational and academic consequences of elementary mathematics environments: Do constructivist innovations and reforms make a difference? *American Educational Research Journal, 38*, 611-652.

Hoadley, C. (2004). Methodological alignment in design-based research. *Educational Psychologist, 39*, 203-212.

Hollan, J., & Stornetta, S. (1992). Beyond being there. In: P. Bauersfeld, J., Bennett & G. Lynch, (Eds) *Proceedings of the International Conference on Computer-Human Interaction (CHI'92*) (pp. 119-125). ACM, New York, NY

Hurme, T-R., Merenluoto, K., Salonen, P., & Järvelä, S. (2007). *Metacognition as shared process in networked mathematical problem solving.* Manuscript submitted for publication.

Ishii, H. and Ullmer, B., 1997. Tangible bits: towards seamless interfaces between people, bits and atoms. In S. Pemberton (Ed.), *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (pp. 234-241). New York: ACM Press.

Järvelä, S., & Häkkinen, P. (2002). Web-based cases in teaching and learning: The quality of discussions and a stage of perspective taking in asynchronous communication. *Interactive Learning Environments, 10*, 1-22.

Järvelä, S. & Järvenoja, H., & Veermans, M. (2007). *Understanding dynamics of motivation in socially shared learning.* Manuscript submitted for publication.

Järvelä, S., & Niemivirta, M. (2001). Motivation in context: Challenges and possibilities in studying the role of motivation in new pedagogical cultures. In S. Volet & S. Järvelä (Eds.), *Motivation in leaning contexts* (pp. 105-127). Amsterdam: Elsevier.

Järvelä, S., & Volet, S. (2004). Motivation in real-life, dynamic and interactive learning environments: Stretching constructs and methodologies. *European Psychologist, 9*, 193-197.

Järvelä, S., Volet, S., & Järvenoja, H. (2007). *Motivation in collaborative learning: new concepts and methods for studying social processes of motivation.* Manuscript submitted for publication.

Järvenoja, H., & Järvelä, S. (2005). How students describe the sources of their emotional and motivational experiences during the learning process: A qualitative approach. *Learning and Instruction, 15*, 465-480.

Jeong, H., & Chi, M. (2007). Knowledge convergence and collaborative learning. *Instructional Science*, 35, 287-316.

Jerman, P., Soller, A., & Muhlenbrock, M. (2001). From mirroring to guiding: A review of state of the art technology for supporting collaborative learning. In P. Dillenbourg, A. Eurelings & K. Hakkarainen (Eds.), *Proceedings of EuroCSCL* (pp. 324-331). Maastricht McLuhan Institute.

Johnson, D. W., & Johnson, R. T. (1999). *Learning together and alone: Cooperative, competitive, and individualistic learning* (5th ed.). Boston: Allyn & Bacon.

Jones, A., & Isroff, K. (2005). Learning technologies: Affective and social issues in computer-supported collaborative learning. *Computers & Education, 44*, 395-408.

Kaplan, F., Do Lenh, S., Bachour, K., Kao, G., Gault, C., & Dillenbourg, P. (in press). Interpersonal computers for higher education. In P. Dillenbourg, J. Huang and M. Cherubini (Eds.), *Collaborative Artefacts and Interactive Furniture*. Computer-Supported Collaborative Learning Series, Springer.

Kirschner, P. A., Sweller, J., & Clark, R. E. (2006). Why minimal guidance during instruction does not work: An analysis of the failure of constructivist, discovery, problem-based experiential and inquiry-based teaching. *Educational Psychologist, 41*, 75-86.

Kollar, I., Fischer, F., & Slotta, J. D. (2007). Internal and external scripts in computer-supported collaborative inquiry learning. *Learning and Instruction,17*, 708-722 .

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

Kuutti, K., & Kaptelinin, V. (1997). Rethinking cognitive tools: From augmentation to mediation. In: P. Marsh, C. Nehaniv & B. Gorayska (Eds) *Proceedings of the Second International Conference on Cognitive Technology* (pp. 31-32). IEEE, Los Alamitos, CA.

Lavie A., & Rosé, C. P. (2004). Optimal ambiguity packing in context-free parsers with interleaved unification. In H. Bunt, J. Carroll & G. Satta (Eds.), *Current issues in parsing technologies* (pp. xx-yy). Dordrecht, The Netherlands: Kluwer Academic Press.

Mäkitalo, K., Häkkinen, P., Järvelä, S., & Leinonen, P. (2002). The mechanisms of common ground in the web-based interaction. *The Internet and Higher Education, 5*, 247-265.

Manlove, S., Lazonder, A., & De Jong, T. (2005, April). *Supporting collaborative self-regulation during online scientific inquiry learning.* Paper presented at AERA 2005 Annual Meeting, Montreal, Canada.

Nova, N., Girardin, F., & Dillenbourg, P. (2005).'Location is not enough!': An empirical study of location-awareness in mobile collaboration. In: H. Ogata & M. Sharples (Eds). *Proceedings of the third IEEE International Workshop on Wireless and Mobile Technologies in Education* (pp. 21-28). Los Alamitos, CA: IEEE Press.

O'Donnell, A. N., & Dansereau, D. F. (1992). Scripted cooperation in student dyads: A method for analyzing and enhancing academic learning and performance. In R. Hertz-Lazarowitz & N. Miller (Eds.), *Interactions in cooperative groups: The theoretical anatomy of group learning* (pp. 120-141). Cambridge, MA: Cambridge University Press.

Olson, J. S., Olson, G. M., & Meader, D. K. (1995). What mix of video and audio is useful for remote real-time work. *Proceedings of the Conference on Human Factors in Computing Systems* (pp.362-368). Denver, CO: Academic Press.

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

Pellegrino, J. W., & Goldman, S. R. (2002). Be careful what you wish for: You may get it: Educational research in the spotlight. *Educational Researcher, 31*(8), 15-17.

Prante, T., Streitz, N.A., & Tandler, P. (2004). Roomware: Computers disappear and interaction evolves. *IEEE Computer, 37*, 47-54.

Resnick, L. B. (1991). Shared cognition: Thinking as social practice. In L. Resnick, J. Levine & S. Teasley (Eds.), *Perspectives on socially shared cognition* (pp. 1-22). Washington, DC: American Psychological Association.

Rosé, C. P., Wang, Y. C., Arguello, J., Stegmann, K., Weinberger, A., & Fischer, F. (in press). Analyzing collaborative learning processes automatically: Exploiting the advances of computational linguistics in computer-supported collaborative learning. *International Journal of Computer-Supported Collaborative Learning*.

Roschelle, J., & Teasley S. D. (1995). The construction of shared knowledge in collaborative problem solving. In C. E. O'Malley (Ed), *Computer-supported collaborative learning*. (pp. 69-97). Berlin: Springer-Verlag.

Russell, D., Streitz, N.A., & Winograd, T. (2005). Building disappearing computers. *Communications of the ACM*, *48*, 42-28.

Salomon, G., & Globerson, T. (1989). When teams do not function the way they ought to. *International Journal of Educational Research., 13*, 89-100.

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

Schellens, T., & Valcke, M. (2005). Collaborative learning in asynchronous discussion groups: What about the impact on cognitive processing? *Computers in Human Behavior, 21*, 957–975.

Schwartz, D. L. (1995). The emergence of abstract dyad representations in dyad problem solving. *The Journal of the Learning Sciences, 4*(3), 321-354.

Singer, J., Marx, R., Krajick, J., & Chambers, J. (2000). Constructing extended inquiry projects: Curriculum materials for science education reform. *Educational Psychologist, 35*, 165-178.

Strijbos, J. W., & Fischer, F. (2007). Methodological challenges for collaborative learning research. *Learning and Instruction*, 17, 389-393.

Summers, J. J. (2006). Effects of collaborative learning in math on sixth graders individual goal orientations from a socio-constructivist perspective. *The Elementary School Journal 106*, 273-290.

Suthers, D., & Hundhausen, C. D. (2003). An experimental study of the effects of representational guidance on collaborative learning processes. *Journal of the Learning Sciences, 12*, 183–218.

Suthers, D., Weiner, A., Connelly, J., & Paolucci., M. (1995). Belvedere: Engaging students in critical discussion of science and public policy issues. In: J. Greer (Ed): *AI-Ed 95, the 7th World Conference on Artificial Intelligence in Education* (pp. 266-273), Washington DC.

Tabak, I. (2004). Synergy: a complement to emerging patterns of distributed scaffolding. *Journal of the Learning Sciences, 13*, 305-335.

Ullmer, B., and Ishii, H. (2000) Emerging Frameworks for Tangible User Interfaces, *IBM Systems Journa*l, 393 (3), pp. 915-931.

Volet, S. E., & Karabenick, S. (2006). Help-seeking in cultural context. In S. Karabenick & R. Newman (Eds.), *Help seeking in academic settings: Goals, groups and contexts*. (pp. 117-150). Mahwah, NJ: Lawrence Erlbaum.

Webb, N. M., & Palincsar, A. S. (1996). Group processes in the classroom. In D. C. Berliner . & R. C. Calfee (Eds.), *Handbook of educational psychology* (pp. 841-873). New York: Simon & Schuster Macmillan.

Wecker, C., & Fischer, F. (2007). Fading scripts in computer-supported collaborative learning: the role of distributed monitoring. In C. Chinn, G. Erkens & S. Puntambekar (Eds.), *Proceedings of the CSCL 2007* (pp. 763-771). Mahwah, NJ: Lawrence Erlbaum Associates.

Wegerif, R. (2007). *Dialogic education and technology: Expanding the space of learning.* Computer-Supported Collaborative Learning Series. Berlin, Germany: Springer

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

Weiser, M. (1993). Ubiquitous computing. *IEEE Computer*, *26*(10), 71-72.

Winne, P. H., Nesbit, J. C., Kumar, V., Hadwin, A. F., Lajoie, S. P., Azevedo, R. A., & Perry, N. E. (2006). Supporting self-regulated learning with gStudy software: The Learning Kit Project. *Technology, Instruction, Cognition and Learning, 3*, 105-113.