Computer-supported collaborative learning: An historical perspective

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Computer-supported collaborative learning (CSCL) is an emerging branch of the learning sciences concerned with studying how people can learn together with the help of computers. As we will see in this essay, such a simple statement conceals considerable complexity. The interplay of learning with technology turns out to be quite intricate. The inclusion of collaboration, computer mediation and distance education has problematized the very notion of learning and called into question prevailing assumptions about how to study it.

Like many active fields of scientific research, CSCL has a complex relationship to established disciplines, evolves in ways that are hard to pinpoint and includes important contributions that seem incompatible. The field of CSCL has a long history of controversy about its theory, methods and definition. Furthermore, it is important to view CSCL as a vision of what may be possible with computers and of what kinds of research should be conducted, rather than as an established body of broadly accepted laboratory and classroom practices. We will start from some popular understandings of the issues of CSCL and gradually reveal its more complex nature. We will review CSCL's historical development and offer our perspective on its future.

CSCL within education

As the study of particular forms of learning, CSCL is intimately concerned with education. It considers all levels of formal education from kindergarten through graduate study as well as informal education, such as museums. Computers have become important in this, with school districts and politicians around the world setting goals of increasing student access to computers and the Internet. The idea of encouraging students to learn together in small groups has also become increasingly emphasized in the broader learning sciences. However, the ability to combine these two ideas (computer support and collaborative learning, or technology and education) to effectively enhance learning remains a challenge—a challenge that CSCL is designed to address.

Computers and education

Computers in the classroom are often viewed with skepticism. They are seen by critics as boring and anti-social, a haven for geeks and a mechanical, inhumane form of training. CSCL is based on precisely the opposite vision: it proposes the development of new software and applications that bring learners together and that can offer creative activities of intellectual exploration and social interaction.

CSCL arose in the 1990s in reaction to software that forced students to learn as isolated individuals. The exciting potential of the Internet to connect people in innovative ways provided a stimulus for CSCL research. As CSCL developed, unforeseen barriers to designing, disseminating and effectively taking advantage of innovative educational software became more and more apparent. A transformation of the whole concept of learning was required, including significant changes in schooling, teaching and being a student.

E-learning at a distance

CSCL is often conflated with e-learning, the organization of instruction across computer networks. E-learning is too often motivated by a naïve belief that classroom content can be digitized and disseminated to large numbers of students with little continuing involvement of teachers or other costs, such as buildings and transportation. There are a number of problems with this view.

First, it is simply not true that the posting of content, such as slides, texts or videos, makes for compelling instruction. Such content may provide important resources for students, just as textbooks always have, but they can only be effective within a larger motivational and interactive context.

Second, online teaching requires at least as much effort by human teachers as classroom teaching. Not only must the teacher prepare materials and make them available by computer, the teacher must motivate and guide each student, through on-going interaction and a sense of social presence. While online teaching allows students from around the world to participate and allows teachers to work from any place with Internet connectivity, it generally significantly increases the teacher effort per student.

Third, CSCL stresses collaboration among the students, so that they are not simply reacting in isolation to posted materials. The learning takes place largely through interactions among students. Students learn by expressing their questions, pursuing lines of inquiry together, teaching each other and seeing how others are learning. Computer support for such collaboration is central to a CSCL approach to e-learning. Stimulating and sustaining productive student interaction is difficult to achieve, requiring skillful planning, coordination and implementation of curriculum, pedagogy and technology.

Fourth, CSCL is also concerned with face-to-face (F2F) collaboration. Computer support of learning does not always take the form of an online communication medium; the computer support may involve, for instance, a computer simulation of a scientific model or a shared interactive representation. In this case, the collaboration focuses on the construction and exploration of the simulation or representation. Alternatively, a group of students might use a computer to browse through information on the Internet and to discuss, debate, gather and present what they found collaboratively. Computer support can take the form of distant or F2F interaction, either synchronously or asynchronously.

Cooperative learning in groups

The study of group learning began long before CSCL. Since at least the 1960s, before the advent of networked personal computers, there was considerable investigation of cooperative learning by education researchers. Research on small groups has an even longer history within social psychology.

To distinguish CSCL from this earlier investigation of group learning, it is useful to draw a distinction between *cooperative* and *collaborative* learning. In a detailed discussion of this distinction, Dillenbourg (1999a) defined the distinction roughly as follows:

> In cooperation, partners split the work, solve sub-tasks individually and then assemble the partial results into the final output. In collaboration, partners do the work 'together.' (p. 8)

He then referred to Roschelle & Teasley's (1995) definition of collaboration:

> This chapter presents a case study intended to exemplify the use of a computer as a cognitive tool for learning that occurs socially. We investigate a particularly important kind of social activity, the *collaborative construction of new problem solving knowledge*. Collaboration is a process by which individuals *negotiate and share meanings* relevant to the problem-solving task at hand…. Collaboration is a coordinated, synchronous activity that is the result of a continued attempt to construct and maintain a shared conception of a problem. (p. 70, emphasis added)

If one is researching learning, this is a significant contrast. In cooperation, the learning is done by individuals, who then contribute their individual results and present the collection of individual results as their group product. Learning in cooperative groups is viewed as something that takes place individually—and can therefore be studied with the traditional conceptualizations and methods of educational and psychological research.

By contrast, in the Roschelle & Teasley characterization of collaboration, learning occurs socially as the collaborative construction of knowledge. Of course, individuals are involved in this as members of the group, but the activities that they engage in are not individual-learning activities, but group interactions like negotiation and sharing. The participants do not go off to do things individually, but remain engaged with a shared task that is constructed and maintained by and for the group as such. The collaborative negotiation and social sharing of *group meanings*—phenomena central to collaboration—cannot be studied with traditional psychological methods.

Collaboration and individual learning

As we have just seen, collaborative learning involves individuals as group members, but also involves phenomena like the negotiation and sharing of meanings—including the construction and maintenance of shared conceptions of tasks—that are accomplished interactively in group processes. Collaborative learning involves individual learning, but is not reducible to it. The relationship between viewing collaborative learning as a group process versus as an aggregation of individual change is a tension at the heart of CSCL.

Earlier studies of learning in groups treated learning as a fundamentally individual process. The fact that the individuals worked in groups was treated as a contextual variable that influenced the individual learning. In CSCL, by contrast, learning is also analyzed as a group process; analysis of learning at both the individual and the group unit of analysis is necessary. This is what makes CSCL methodologically unique, as we shall see later in this essay.

To some extent, CSCL has emerged in reaction to previous attempts to use technology within education and to previous approaches to understand collaborative phenomena with the traditional methods of the learning sciences. The learning sciences as a whole have shifted from a narrow focus on individual learning to an incorporation of both individual and group learning, and the evolution of CSCL has paralleled this movement.

The Historical Evolution of CSCL

The beginnings

Three early projects—the ENFI Project at Gallaudet University, the CSILE project at the University of Toronto, and the Fifth Dimension Project at the University of California San Diego—were forerunners for what was later to emerge as the field of CSCL. All three involved explorations of the use of technology to improve learning related to literacy.

The ENFI Project produced some of the earliest examples of programs for computer-aided composition or "CSCWriting" (Bruce & Rubin, 1993; Gruber, Peyton, & Bruce, 1995). Students who attend Gallaudet are deaf or hearing impaired; many such students enter college with deficiencies in their written-communication skills. The goal of the ENFI Project was to engage students in writing in new ways: to introduce them to the idea of writing with a 'voice' and writing with an audience in mind. The technologies developed, though advanced for the time, might seem rudimentary by today's standards. Special classrooms were constructed in which desks with computers were arranged in a circle. Software resembling today's chat programs was developed to enable the students and their instructor to conduct textually-mediated discussions. The technology in the ENFI project was designed to support a new form of meaning-making by providing a new medium for textual communication.

Another early, influential project was undertaken by Bereiter and Scardamalia at the University of Toronto. They were concerned that learning in schools is often shallow and poorly motivated. They contrasted the learning that takes place in classrooms with the learning that occurs in "knowledge-building communities" (Bereiter, 2002; Scardamalia & Bereiter, 1996), like the communities of scholars that grow up around a research problem. In the CSILE Project (Computer Supported Intentional Learning Environment), later known as Knowledge Forum, they developed technologies and pedagogies to restructure classrooms as knowledge-building communities. Like the ENFI Project, CSILE sought to make writing more meaningful by engaging students in joint text production. The texts produced in each case were quite different, however. The ENFI texts were conversational; they were produced spontaneously and were generally not preserved beyond the completion of a class. CSILE texts, on the other hand, were archival, like conventional scholarly literatures.

As was the case for CSILE, the Fifth Dimension (5thD) Project began with an interest in improving reading skills (Cole, 1996). It started with an after-school program organized by Cole and colleagues at Rockefeller University. When the Laboratory of Comparative Human Cognition (LCHC) moved to UCSD, the 5thD was elaborated into an integrated system of mostly computer-based activities selected to enhance students' skills for reading and problem solving. The "Maze," a board-game type layout with different rooms representing specific activities, was introduced as a mechanism for marking student progress and coordinating participation with the 5thD. Student work was supported by more-skilled peers and by undergraduate volunteers from the School of Education. The program was originally implemented at four sites in San Diego, but was eventually expanded to multiple sites around the world (Nicolopoulou & Cole, 1993).

All of these projects—ENFI, CSILE and 5thD—shared a goal of making instruction more oriented toward meaning making. All three turned to computer and information technologies as resources for achieving this goal, and all three introduced novel forms of organized social activity within instruction. In this way, they laid the groundwork for the subsequent emergence of CSCL.

From conferences to a global community

In 1983, a workshop on the topic of "joint problem solving and microcomputers" was held in San Diego. Six years later, a NATO-sponsored workshop was held in Maratea, Italy. The 1989 Maratea workshop is considered by many to mark the birth of the field, as it was the first public and international gathering to use the term "computer-supported collaborative learning" in its title.

The first full-fledged CSCL conference was organized at Indiana University in the fall of 1995. Subsequent international meetings have taken place at least biennially, with conferences at the University of Toronto in 1997, Stanford University in 1999, the University of Maastricht in the Netherlands in 2001, the University of Colorado in 2002, the University of Bergen in Norway in 2003, and the National Central University in Taiwan in 2005.

A specialized literature documenting theory and research in CSCL has developed since the NATO-sponsored workshop in Maratea. Four of the most influential monographs are: Newman, Griffin, and Cole (1989) *The Construction Zone*, Bruffee (1993) *Collaborative Learning*, Crook (1994) *Computers and the Collaborative Experience of Learning*, and Bereiter (2002) *Education and Mind in the Knowledge Age*.

Additionally, there have been a number of edited collections specifically focusing on CSCL research: O'Malley (1995) *Computer-Supported Collaborative Learning*, Koschmann (1996b) *CSCL: Theory and Practice of an Emerging Paradigm*, Dillenbourg (1999b) *Collaborative Learning: Cognitive and Computational Approaches*, and Koschmann, Hall & Miyake (2002) *CSCL2: Carrying Forward the Conversation*.

A book series on CSCL published by Kluwer (now Springer) includes five volumes to date (Andriessen, Baker, & Suthers, 2003; Bromme, Hesse, & Spada, 2005; Goodyear *et al.*, 2004; Strijbos, Kirschner, & Martens, 2004; Wasson, Ludvigsen, & Hoppe, 2003). The CSCL conference proceedings have been the primary vehicle for publications in the field. A number of journals have also played a role, particularly the *Journal of the Learning Sciences*. An *International Journal of Computer-Supported Collaborative Learning* will start publishing in 2006. Although the community was centered in Western Europe and Northern America in its early years, it has evolved into a rather well-balanced international presence (Hoadley, 2005; Kienle & Wessner, 2005). The 2005 conference in Taiwan and the establishment of the new international journal were planned to make the community truly global.

From artificial intelligence to collaboration support

The field of CSCL can be contrasted with earlier approaches to using computers in education. Koschmann (1996a) identified the following historical sequence of approaches: (a) computer-assisted instruction, (b) intelligent tutoring systems, (c) Logo as Latin, (d) CSCL. (a) Computer-assisted instruction was a behaviorist approach that dominated the early years of educational computer applications beginning in the 1960s. It conceived of learning as the memorization of facts. Domains of knowledge were broken down into elemental facts that were presented to students in a logical sequence through computerized drill and practice. Many commercial educational software products still take this approach. (b) Intelligent tutoring systems were based on a cognitivist philosophy that analyzed student learning in terms of mental models and potentially faulty mental representations. They rejected the behaviorist view that learning could be supported without concern for how students represented and processed knowledge. Considered particularly promising in the 1970s, this approach created computer models of student understanding and then responded to student actions based on occurrences of typical errors identified in student mental models. (c) Efforts in the 1980s, epitomized by the teaching of the Logo programming language, took a constructivist approach, arguing that students must build their knowledge themselves. It provided stimulating environments for students to explore and to discover the power of reasoning, as illustrated in software programming constructs: functions, subroutines, loops, variables, recursion, etc. (d) During the mid-1990s, CSCL approaches began to explore how computers could bring students together to learn collaboratively in small groups and in learning communities. Motivated by social constructivist and dialogical theories, these efforts sought to provide and support opportunities for students to learn together by directed discourse that would construct shared knowledge.

At the time when mainframe computers were becoming available for school usage and micro-computers started to appear, artificial intelligence (AI) was near the height of its popularity. So it was natural that computer scientists interested in educational applications of computer technology would be attracted by the exciting promises of AI. AI is computer software that closely mimics behaviors that might be considered intelligent if done by a human (e.g., to play chess by considering the pros and cons of alternative sequences of legal moves). Intelligent tutoring systems are a prime example of AI, because they replicate the actions of a human tutor— providing responses to student input (e.g., detailed steps in solving a math problem) by analyzing the student problem-solving strategy and offering advice by comparing student actions to programmed models of correct and erroneous understanding. This is still an active research area within the learning sciences, but is limited to domains of knowledge where mental models can be algorithmically defined.

In its most ambitious form, the AI approach sought to have the computer handle certain teaching or guiding functions that would otherwise require a human teacher's time and intervention. Within CSCL, the focus of learning is on learning through collaboration with other students rather than directly from the teacher. Therefore, the role of the computer shifts from providing instruction—either in the form of facts in computer-aided instruction or in the form of feedback from intelligent tutoring systems—to supporting collaboration by providing media of communication and scaffolding for productive student interaction.

The primary form of collaboration support is for the computer (i.e., the network of computers, typically connected over the Internet) to provide a medium of communication. This may take the form of email, chat, discussion forums, videoconferencing, instant messaging, etc. CSCL systems typically provide a combination of several media and add special functionality to them.

In addition, CSCL software environments provide various forms of pedagogical support or scaffolding for collaborative learning. These may be implemented with rather complex computational mechanisms, including AI techniques. They can offer alternative views on the ongoing student discussion and emerging shared information. They can provide feedback, possibly based on a model of group inquiry. They can support sociability by monitoring interaction patterns and providing feedback to the students. In most cases, the role of the computer is secondary to the interpersonal collaboration process among the students (and, often, the teacher, tutor or mentor). The software is designed to support, not replace, these human, group processes.

The shift from mental models of individual cognition to support for collaborating groups had enormous implications for both the focus and the method of research on learning. The gradual acceptance and unfolding of these implications has defined the evolution of the field of CSCL.

From individuals to interacting groups

At about the time of the first biannual CSCL conference, Dillenbourg, et al. (1996) analyzed the state of evolution of research on collaborative learning as follows.

> For many years, theories of collaborative learning tended to focus on how *individuals* function in a group. This reflected a position that was dominant both in cognitive psychology and in artificial intelligence in the 1970s and early 1980s, where cognition was seen as a product of individual information processors, and where the context of social interaction was seen more as a background for individual activity than as a focus of research. More recently, *the group itself has become the unit of analysis* and the focus has shifted to more emergent, socially constructed, *properties of the interaction*.
>
> In terms of empirical research, the initial goal was to establish whether and under what circumstances collaborative learning was more effective than learning alone. Researchers controlled several independent variables (size of the group, composition of the group, nature of the task, communication media, and so on). However, these variables interacted with one another in a way that made it almost impossible to establish causal links between the conditions and the effects of collaboration. Hence, empirical studies have more recently started to focus less on *establishing parameters for effective collaboration* and more on trying to *understand the role that such variables play in mediating interaction*. This shift to a more process-oriented account requires *new tools for analyzing and modeling interactions*. (p. 189, emphasis added)

The research reviewed by Dillenbourg et al.—which studied the effects of manipulating collaboration variables on the measures of individual learning—did not produce clear results. Effects of gender or group composition (i.e., heterogeneous or homogeneous competence levels) might be completely different at different ages, in different domains, with different teachers, and so on. This not only violated methodological assumptions of variable independence, but raised questions about how to understand what was behind the effects. To get behind the effects meant to understand in some detail what was going on in the group interactions that might cause the effects. This, in turn, required the development of methodologies for analyzing and interpreting group interactions as such. The focus was no longer on what might be taking place “in the heads” of individual learners, but what was taking place between and among them in their interactions.

From mental representations to interactional meaning making

The shift to the group unit of analysis coincided with a focus on the community as the agent of situated learning (Lave, 1991) or collaborative knowledge building (Scardamalia & Bereiter, 1991). But it also called for the elaboration of a social theory of mind, such as Vygotsky (1930/1978) had begun to outline, which could clarify the relation of individual learners to collaborative learning in groups or communities.

According to Vygotsky, individual learners have different developmental capabilities in collaborative situations than when they are working alone. His concept of the "zone of proximal development" is defined as a measure of the difference between these two capabilities. This means that one cannot measure the learning—even the individual learning—that takes place in collaborative situations with the use of pre- and post-tests that measure capabilities of the individuals when they are working alone. To get at what takes place during collaborative learning, it does not help to theorize about mental models in the heads of individuals, because that does not capture the shared meaning making that is going on during collaborative interactions.

Collaboration is primarily conceptualized as a process of shared meaning construction. The meaning making is not assumed to be an expression of mental representations of the individual participants, but is an interactional achievement. Meaning making can be analyzed as taking place across sequences of utterances or messages from multiple participants. The meaning is not attributable to individual utterances of individual students because the meaning typically depends upon indexical references to the shared situation, elliptical references to previous utterances and projective preferences for future utterances (Stahl, 2006).

From quantitative comparisons to micro case studies

To observe learning in collaborative situations is different from observing it for isolated learners. First, in situations of collaboration, participants necessarily visibly display their learning as part of the process of collaboration. Second, the observations take place across relatively short periods of group interaction, rather than across long periods between pre- and post-tests.

Ironically, perhaps, it is in principle easier to study learning in groups than in individuals. That is because a necessary feature of collaboration is that the participants display for each other their understanding of the meaning that is being constructed in the interaction. Utterances, texts and diagrams that are produced during collaboration are designed by the participants to display their understanding. That is the basis for successful collaboration. Researchers can take advantage of these displays (assuming that they share the participants' interpretive competencies and can capture an adequate record of the displays, e.g., on digital video). Researchers can then reconstruct the collaborative process through which group participants constructed shared meaning, which was learned as a group.

Methodologies like conversation analysis (Sacks, 1992; ten Have, 1999) or video analysis (Koschmann, Stahl, & Zemel, 2005) based on ethnomethodology (Garfinkel, 1967) produce detailed case studies of collaborative meaning making. These case studies are not merely anecdotal. They can be based on rigorous scientific procedures with intersubjective validity even though they are interpretive in nature and are not quantitative. They can also represent generally applicable results, in that the methods that people use to interact are widely shared (at least within appropriately defined communities or cultures).

How can the analysis of interactional methods help to guide the design of CSCL technologies and pedagogies? This question points to the complex interplay between education and computers in CSCL.

The interplay of learning and technology in CSCL

The traditional conception of learning

Edwin Thorndike (1912), a founder of the traditional educational approach, once wrote:

> If, by a miracle of mechanical ingenuity, a book could be so arranged that only to him who had done what was directed on page one would two become visible, and so on, much that now requires personal instruction could be managed by print …. Children [could] be taught, moreover to use materials in a manner that will be most useful in the long run. (p. 165)

This quotation is notable in two respects. For one, it suggests that the central idea of computer-aided instruction long preceded the actual development of computers; but, more importantly, it also shows how the goal of research in educational technology is closely tied, indeed indistinguishable from, the conventional goal of educational research, namely to enhance learning as it is operationally defined. Thorndike envisioned an educational science in which all learning is measurable and, on this basis, by which all educational innovations could be experimentally evaluated. Historically, research on educational technology has been tied to this tradition and represents a specialization within it (cf., Cuban, 1986).

In the past, educational researchers have treated learning as a purely psychological phenomenon. Learning is seen to have three essential features: First, it represents a response to and recording of experience. Second, learning is always treated as a change that occurs over time. Finally, learning is generally seen as a process not available to direct inspection (Koschmann, 2002a). This formulation is so culturally entrenched that it is difficult to conceive of learning in any other way. It rests upon established traditions in epistemology and philosophy of mind.

Contemporary philosophy has called these traditions into question, however. The so-called "edifying philosophers" (Rorty, 1974)—James, Dewey, Wittgenstein and Heidegger—rebelled against the view of learning as an inaccessible event in which knowledge is inscribed in an individual mind. They aspired to construct a new view of learning and knowing, one that properly located it in the world of everyday affairs. CSCL embraces this more situated view of learning, thereby rejecting the foundations of conventional educational research. CSCL locates learning in meaning negotiation carried out in the social world rather than in individuals' heads. Of the various socially oriented theories of learning, social practice theory (Lave & Wenger, 1991) and dialogical theories of learning (e.g., Hicks, 1996) speak most directly to a view of learning as socially organized meaning construction. Social practice theory focuses on one aspect of meaning negotiation: the negotiation of social identity within a community. Dialogical theories locate learning in the emergent development of meaning within social interaction. Taken together, they comprise a basis for a new way of thinking about and studying learning.

Designing technology to support group meaning making

The goal for design in CSCL is to create artifacts, activities and environments that enhance the practices of group meaning making. Rapid advances in computer and communication technologies in recent decades, like the Internet, have dramatically changed the ways in which we work, play, and learn. No form of technology, however, no matter how cleverly designed or sophisticated, has the capacity, in and of itself, to change practice. To create the possibility of an enhanced form of practice requires more multifaceted forms of design (bringing in expertise, theories and practices from various disciplines): design that addresses curriculum (pedagogical and didactic design), resources (information sciences, communication sciences), participation structures (interaction design), tools (design studies), and surrounding space (architecture).

As the title of a commentary by LeBaron (2002) suggests, "Technology does not exist independent of its use." Substitute 'activities, artifacts, and environments' for 'technology' and the message remains the same—these elements themselves cannot define new forms of practice, but are instead constituted within practice. An environment for a desired form of practice becomes such through the organized actions of its inhabitants. Tools and artifacts are only tools and artifacts in the ways in which they are oriented to and made relevant by participants in directed practice. Even activities are only rendered recognizable as such in the ways that participants orient to them as ordered forms of joint action.

Design of software for CSCL, therefore, must be coupled with analysis of the meanings constructed within emergent practice. Meanings reflect past experience and are open to endless negotiation and re-evaluation. Furthermore, neither analysts nor participants have privileged access to others' subjective interpretations. Despite these issues, participants routinely engage in coordinated activity and operate as if shared understanding was both possible and being achieved. A fundamental question, therefore, is how is this done? In order to design technology to support collaborative learning and knowledge building, we must understand in more detail how small groups of learners construct shared meaning using various artifacts and media.

The question of how *intersubjectivity* is accomplished has been taken up in a variety of specialized disciplines such as pragmatics (Levinson, 2000; Sperber & Wilson, 1982), social psychology (Rommetveit, 1974), linguistic anthropology (Hanks, 1996), and sociology (cf. Goffman, 1974), especially sociological research in the ethnomethodological tradition (Garfinkel, 1967; Heritage, 1984). The problem of intersubjectivity is of particular relevance for those who wish to understand how learning is produced within interaction. Learning can be construed as the act of bringing divergent meanings into contact (Hicks, 1996), and instruction as the social and material arrangements that foster such negotiation. The analysis of meaning-making praxis calls for the appropriation of the methods and concerns of psychology (especially the discursive and cultural varieties), sociology (especially the micro-sociological and ethnomethodologically informed traditions), anthropology (including linguistic anthropology and anthropologies of the built environment), pragmatics, philosophy, communication studies, organizational science, and others.

CSCL research has both analytic and design components. Analysis of meaning making is inductive and indifferent to reform goals. It seeks only to discover what people are doing in moment-to-moment interaction, without prescription or assessment. Design, on the other hand, is inherently prescriptive—any effort toward reform begins from the presumption that there are better and worse ways of doing things. To design for improved meaning making, however, requires some means of rigorously studying praxis. In this way, the relationship between analysis and design is a symbiotic one—design must be informed by analysis, but analysis also depends on design in its orientation to the analytic object (Koschmann *et al.*, 2005).

CSCL must continue with its work of self-invention. New sources of theory must be introduced, analyses of learner practice presented, and artifacts produced accompanied by theories of how they might enhance meaning-making. The design of CSCL technology, which opens new possibilities for collaborative learning, must be founded on an analysis of the nature of collaborative learning.

The analysis of collaborative learning

Koschmann (2002b) presented a programmatic description of CSCL in his keynote at CSCL 2002:

> CSCL is a field of study centrally concerned with meaning and the practices of meaning-making in the context of joint activity, and the ways in which these practices are mediated through designed artifacts. (p. 18)

The aspect of collaborative learning that is perhaps hardest to understand in detail is what may be called "practices of meaning-making in the context of joint activity," *intersubjective learning* (Suthers, 2005) or *group cognition* (Stahl, 2006). This is learning that is not merely accomplished interactionally, but is actually *constituted* of the interactions between participants. Following Garfinkel, Koschmann et al. (2005) argue for the study of "member's methods" of meaning making: "how participants in such [instructional] settings actually go about *doing* learning" (emphasis in original). In addition to understanding how the cognitive processes of participants are influenced by social interaction, we need to understand how learning events themselves take place in the interactions between participants.

The study of joint meaning making is not yet prominent within CSCL practice. Even where interaction processes (rather than individual learning outcomes) are examined in detail, the analysis is typically undertaken by assigning coding categories and counting pre-defined features. The codes, in effect, substitute preconceived categories of behavior for the phenomenon of interest rather than seeking to discover those phenomena in their unique situations (Stahl, 2002).

A few studies published in the CSCL literature have directly addressed this problem of describing the constituting of intersubjectivity in interaction (for example, Koschmann *et al.*, 2003; Koschmann *et al.*, 2005; Roschelle, 1996; Stahl, 2006). Roschelle's early study designed software especially to support meaning making related to physics, defined student activities to engage learners in joint problem solving, and analyzed their collaborative practices in micro detail. Koschmann's work has generally focused on participants' methods of *problematization*: how groups of students collectively characterize a situation as problematic and as requiring further specific analysis.

Stahl (2006) argues that small groups are the most fruitful unit for the study of intersubjective meaning making, for several reasons. Most simply, small groups are where members' methods for intersubjective learning can be observed. Groups of several members allow the full range of social interactions to play out, but are not so large that participants and researchers alike necessarily lose track of what is going on. The shared construction of meaning is most visible and available for research at the small-group unit of analysis, where it appears as *group cognition*. Moreover, small groups lie at the boundary of, and mediate between, individuals and a community. The knowledge building that takes place within small groups becomes "internalized by their members as individual learning and externalized in their communities as certifiable knowledge" (Stahl, 2006). However, small groups should not be the only social granularity studied. Analysis of large-scale changes in communities and organizations may lead to an understanding of emergent social-learning phenomena as well as elucidate the role of embedded groups in driving these changes.

The study of the interactional accomplishment of intersubjective learning or group cognition gives rise to interesting questions that are among the most challenging facing any social-behavioral science, and even touch upon our nature as conscious beings. Do cognitive phenomena take place trans-personally in group discourse? How is it possible for learning, usually conceived of as a cognitive function, to be distributed across people and artifacts? How can we understand knowledge as accomplished practice rather than as a possession or even predisposition?

The analysis of computer support

In CSCL contexts, the group interactions among individuals are mediated by computer environments. The second half of Koschmann's programmatic definition of the domain of CSCL is "the ways in which these practices [meaning-making in the context of joint activity] are mediated through designed artifacts." Computer support for intersubjective meaning making is what makes the field unique.

The technology side of the CSCL agenda focuses on the design and study of fundamentally social technologies. To be fundamentally social means that the technology is designed specifically to mediate and encourage social acts that constitute group learning and lead to individual learning. Design should leverage the unique opportunities provided by the technology rather than replicate support for learning that could be done through other means, or (worse) try to force the technology to be something for which it is not well suited. What is unique to information technology that can potentially fill this role?

- Computational media are reconfigurable. Representations are dynamic: it is easy to move things around and undo actions. It is easy to replicate those actions elsewhere: one can bridge time and space. These features make information technology attractive as a "communication channel," but we should exploit technology for its potential to make new interactions possible, not try to force it to replicate face-to-face interaction.
- Computer-mediated communication environments "turn communication into substance" (Dillenbourg, 2005). A record of activity as well as product can be kept, replayed, and even modified. We should explore the potential of the persistent record of interaction and collaboration as a resource for intersubjective learning.
- Computational media can analyze workspace state and interaction sequences, and reconfigure itself or generate prompts according to features of either. We should explore the potential of adaptive media as an influence on the course of intersubjective processes, and take advantage of its ability to prompt, analyze and selectively respond.

Human communication and the use of representational resources for this communication is highly flexible: technologies can open possibilities, but they cannot "fix" meanings or even specify communicative functions (Dwyer & Suthers, 2005). Informed by this fact, CSCL research should identify the unique advantages of computational media, and explore how these are used by collaborators and how they influence the course of their meaning making. Then we will design technologies that offer collections of features through which participants can interactionally engage in learning with flexible forms of guidance.

The multi-disciplinarity of CSCL

CSCL can presently be characterized as consisting of three methodological traditions: experimental, descriptive and iterative design.

Many empirical CSCL studies follow the dominant *experimental* paradigm that compares an intervention to a control condition in terms of one or more variables (e.g., Baker & Lund, 1997; Rummel & Spada, 2005; Suthers & Hundhausen, 2003; Van Der Pol, Admiraal, & Simons, 2003; Weinberger *et al.*, 2005). Data analysis in most of these studies is undertaken by "coding and counting": interactions are categorized and/or learning outcomes measured, and group means are compared through statistical methods in order to draw general conclusions about the effects of the manipulated variables on aggregate (average) group behavior. These studies do not directly analyze the accomplishment of intersubjective learning. Such an analysis must examine the structure and intention of unique cases of interaction rather than count and aggregate behavioral categories.

The ethnomethodological tradition (exemplified in CSCL by Koschmann *et al.*, 2003; Koschmann *et al.*, 2005; Roschelle, 1996; Stahl, 2006) is more suited for *descriptive* case analyses. Video or transcripts of learners or other members of the learning community are studied to uncover the methods by which groups of participants accomplish learning. The grounded approach is data-driven, seeking to discover patterns in the data rather than imposing theoretical categories. The analysis is often micro-analytic, examining brief episodes in great detail. Descriptive methodologies are well suited to existentially quantified claims (e.g., that a community sometimes engages in a given practice). Yet, as scientists and designers we would like to make causal generalizations about the effects of design choices. Descriptive methodologies are less suited for providing quantitative proof that an intervention has an effect, which is the province of experimental methodology, although it can often understand how very general practices work.

The traditional analytic methods of experimental psychology miss the "member methods" through which collaborative learning is accomplished—intersubjective meaning making. But this does not imply that all CSCL research should be ethnomethodological. Rather, the foregoing considerations suggest that we explore hybrid research methodologies (Johnson & Onwuegbuzie, 2004). Experimental designs can continue to compare interventions, but the comparisons would be made in terms of the features identified in micro-analyses of how information technology influences and is appropriated for members' methods of joint meaning making. Conceptually, the process analysis changes from "coding and counting" to "exploring and understanding" ways in which design variables influence support for meaning-making. Such analyses are time intensive: we should explore, as research aids, the development of instrumentation for learning environments and automated visualization and querying of interaction logs (as in Cakir *et al.*, 2005; Donmez *et al.*, 2005). Conversely, traditional analyses, especially measures of learning outcomes but also "coding and counting," might also be retained to obtain quick indicators of where more detailed analyses are merited, thereby focusing the detail work (as in Zemel, Xhafa, & Stahl, 2005).

The *iterative design* tradition is exemplified by Fischer & Ostwald (2005), Lingnau, et al. (2003) and Guzdial et al. (1997). Driven by the interactions among evolving theory, informal observations and stakeholder engagement, design-oriented researchers continuously improve the artifacts intended to mediate learning and collaboration. Their research is not necessarily either qualitative or quantitative, but may also be "quisitive" (Goldman, Crosby, & Shea, 2004)—explorative and interventionist. It is not enough to just observe people's behaviors when they use new software. We need to explore the "space" of possible designs, pushing into new areas and identifying promising features that should receive further study under the other methodological traditions. Designers need to conduct microanalyses of collaborative learning with and through technology in order to identify the features of designed artifacts that seem to be correlated with effective learning. When a new technical intervention is tested, experimental methods can be used to document significant differences while descriptive methods can document how the interventions mediated collaborative interactions differently. A conversation between the theoretical assumptions of ethnomethodology and those of design can lead to a "technomethodology" that changes the very objectives of design (Button & Dourish, 1996).

A potential limitation of descriptive methodologies should be noted. If we focus on finding examples of how members accomplish effective learning, we may miss abundant examples of how they also fail to do so. Yet in order to find that something is not there, we need to have an idea of what we are looking for. A purely data-driven approach that derives theory, but never applies it, won't be adequate. Descriptive methods can be modified to address this need. Common patterns found in successful learning episodes subsequently become the theoretical categories we look for elsewhere with analytic methods, and perhaps do not find in instances of unsuccessful collaboration. Having identified where the successful methods were *not* applied, we then examine the situation to determine what contingency was missing or responsible. Unique and un-reproducible instances where collaboration using technology breaks down in interesting ways can often provide the deepest insights into what is happening, but what is normally taken for granted and invisible. Care should be taken, however, to make sure that in finding case examples where the interactional accomplishment of learning is absent we do not fail to notice where something else of value to the participants *is* being accomplished! For example, establishment and maintenance of individual and group identity are worthwhile accomplishments as far as the participants are concerned (Whitworth, Gallupe, & McQueen, 2000), and indeed are a form of situated learning, even though researchers may initially identify it as "off topic" social chatting.

CSCL research in the future

We have seen that research in CSCL must respond to multiple goals and constraints. The research community necessarily includes people from a variety of professional and disciplinary backgrounds and trainings. They bring with them different research paradigms, contrasting views of data, analysis methods, presentation formats, concepts of rigor and technical vocabularies. They come from around the world with various cultures and native languages. CSCL is a rapidly evolving field, located at the intersection of other fields (like the learning sciences generally) that are themselves undergoing continuous change. Community participants at any given time are operating within diverse conceptions of what CSCL is all about. For instance, Sfard (1998) defines two broad and irreconcilable metaphors of learning that are necessarily relevant to CSCL: the acquisition metaphor, in which learning consists of individuals acquiring knowledge stored in their minds, and the participation metaphor, in which learning consists of increasing participation in communities of practice. Lipponen, Hakkarainen & Paavola, (2004) adds a third metaphor based on Bereiter (2002) and Engeström (1987): the knowledge creation metaphor, in which new knowledge objects or social practices are created in the world through collaboration. Consequently, it is hard to present a well-defined, consistent and comprehensive definition of

CSCL theory, methodology, findings or best practices. Perhaps one must conclude that CSCL today necessarily pursues seemingly irreconcilable approaches—as Sfard argues. One can speculate that more integrated, hybrid approaches may be possible in the future, as we have tried to suggest.

Research methodology in CSCL is largely trichotomized between experimental, descriptive and iterative design approaches. Although sometimes combined within a single research project, the methodologies are even then typically kept separate in companion studies or separate analyses of a single study. Different researchers sometimes wear different hats on the same project, representing different research interests and methodologies. This situation may still be productive: the experimentalists continue to identify variables that effect general parameters of collaborative behavior, the ethnomethodologists identify patterns of joint activity that are essential to the meaning-making, and designers innovate to creatively adapt new technological possibilities. Soon, however, experimentalists within CSCL may start to focus on the dependent variables that directly reflect the phenomenon of interest to the descriptive researchers (Fischer & Granoo, 1995), ethnomethodologists may look for *predictive* regularities in technology-mediated meaning making that can inform design, and the designers may generate and assess promising new technology affordances in terms of the meaning-making activities they enable. Mutual assistance and closer collaboration may be possible through hybrid methodologies, for example by applying richer descriptive analytic methods to the problem of understanding the implications of experimental manipulations and new designs, or through computer support for our own meaning-making activities as researchers.

CSCL researchers form a community of inquiry that is actively constructing new ways to collaborate in the design, analysis and implementation of computer support for collaborative learning. A broad range of research methods from the learning sciences may be useful in analyzing computer-supported collaborative learning. Having appropriated ideas, methods and functionality from cognate fields, CSCL may in its next phase collaboratively construct new theories, methodologies and technologies specific to the task of analyzing the social practices of intersubjective meaning making in order to support collaborative learning. The authors of this essay have argued that CSCL requires a focus on the meaning-making practices of collaborating groups and on the design of technological artifacts to mediate interaction, rather than a focus on individual learning. Whether this focus can, will or should lead to a coherent theoretical framework and research methodology for CSCL remains to be seen.

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