Computer-Supported Collaborative Learning

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The vision of Computer-Supported Collaborative Learning (CSCL) transforms common approaches to online education, harnessing the power of collaboration and identifying the requirements for achieving its potentials. When this chapter was revised in 2020, the Coronavirus pandemic had rendered the makeover of educational practice urgent worldwide. Suddenly, teachers, students, parents and politicians realized that online learning was necessary, but that few people knew how to make it pedagogically effective. The research field of CSCL has been researching the complex and intertwined issues involved in this for many years. CSCL proposes a set of responses to realize the possibilities of online learning while recognizing the multiple areas requiring innovative approaches for this vision to be achieved.

During the pandemic, teachers turned to communication technologies like Zoom, to course organizers like Blackboard, to information sites like Wikipedia and to social media apps like Twitter. People assumed that teachers could continue to provide instruction in traditional ways through these digital media. However, none of these applications were designed to support learning. Communication media were devised for business meetings, course management systems were to administer classrooms, online info services provide de-contextual facts and social media exchange personal opinions. In contrast, CSCL aims to support collaboration that builds beyond individual ideas and isolated facts to create shared knowledge.

The goal of CSCL can be described using multiple terminologies, stemming from different disciplinary traditions. This chapter discusses CSCL in terms of each of these conceptualizations:

- *Collaborative knowledge building*: constructing knowledge artifacts like scientific theories by groups of students building on each other's contributions.
- *Dialogic interaction*: merging ideas by discussion from different people's perspectives.
- *Intersubjective meaning making:* developing shared sense of topics through discourse, including emotion and gesture.
- *Group cognition*: allowing knowledge to emerge in group processes, rather than just in individual minds.

CSCL is a field of study that necessarily combines multiple disciplines. Because it is "computer supported," it involves digital technology. However, no application is a CSCL tool by itself. It must be appropriately adopted by its users within a CSCL context. For instance, there needs to be an established culture of collaborative learning, i.e., a set of CSCL pedagogy practices. To achieve this, the technology must be designed in accordance with CSCL theories, which describe how collaborative learning takes place. Technologies need to be developed within iterative cycles of realistic trials with students

to analyze how the hardware and software are actually used to build group knowledge. Accordingly, CSCL is a multi-faceted effort, integrating:

- *Theory*: understandings of the nature of group-level processes involved in achieving effective collaborative learning.
- *Methodology*: ways to analyze the intersubjective meaning making that takes place in small-group dialogical interaction.
- *Pedagogy*: educational approaches to establish group practices that de-emphasize individual competition in favor of collaborative knowledge building.
- *Technology*: artifacts designed to promote group cognition and demonstrated to foster desirable group practices.

CSCL is an innovative conceptualization and implementation of learning and thinking. It takes advantage of technological opportunities for increased networking of students as well as increased support by informational and computational resources. Not all learning should be CSCL style; teachers should design CSCL sessions and orchestrate them into well-designed sequences of individual, group and classroom learning. CSCL represents a significant departure from teacher-centered and individual-student-focused learning, which offers complementary forms of learning. The sections of this chapter explain the CSCL paradigm in four stages:

- How CSCL is a visionary approach to education.
- How CSCL technology, analysis, pedagogy and theory emerged over 25 years.
- How CSCL presents an innovative approach to online learning.
- How CSCL can develop in the future.

CSCL Within Education

As the study of certain 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. Computer technology has become important at all levels of education, with school districts and politicians around the world setting goals of increasing student access to computers and the Internet. Importantly, computer networks can bring students together across time and space to collaborate — both asynchronously and in real time, remotely and face-to-face. The idea of encouraging students to learn together in small groups has also become increasingly emphasized in the Learning Sciences, as seen in many chapters of this *Handbook*. 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. Critics see them 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 to offer creative activities of intellectual exploration and social interaction.

CSCL arose in the 1990s in reaction against 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 increasingly apparent. A transformation of the whole concept of learning was required, including significant changes in schooling, teaching and being a student. Many of the necessary changes are reflected in the educational approaches presented in Part 1 of this *Handbook*, for instance adopting educational frameworks such as knowledge building (Scardamalia & Bereiter, Chapter 18, this volume), scaffolding (Reiser & Tabak, Chapter 3, this volume) or situativity (Engeström & Greeno, Chapter 7, this volume).

Online Learning at a Distance

CSCL is often conflated with online learning, the organization of instruction across computer networks. Online 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 several 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 supply important resources for students—just as textbooks always have—but they can only be effective within a larger motivational and interactive social 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 has generally been found to significantly increase teacher effort per student.

Third, CSCL stresses collaboration among students, so that they are not simply reacting in isolation to posted materials. The learning is done by groups, through interaction among students. Student groups learn collaboratively: by expressing 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 online learning. Stimulating and sustaining productive student interaction is difficult to achieve; it requires skillful planning, coordination and implementation of curriculum, pedagogy and technology. It presupposes the establishment of a culture of collaboration in classrooms, as opposed to competition (e.g., testing and grading).

Fourth, CSCL is also concerned with face-to-face (F2F) collaboration. Computer support of collaborative learning does not always take place through an online communication medium; the computer support may involve the construction and exploration of a computer simulation of a scientific model or a shared interactive 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 (Enyedy & Stevens, this volume).

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 (1999) 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 offered as an example Roschelle & Teasley's (1995) description of collaboration in which a form of social learning is accomplished using a computer as a cognitive tool:

> 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)

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 and 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 primarily 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—involve a *socio*-logic. We call this *meaning making*. It is the group as a whole that conducts the problem solving, shares new meaning, and builds knowledge or group practices. Understandings built in collaboration rest upon epistemological assumptions that are different from those typically employed in educational research and call for a different set of research methods.

Collaboration and Individual Learning

As we have just seen, collaborative learning involves individuals as group members, but also involves group phenomena like the negotiation and sharing of meanings—including the construction and maintenance of shared conceptions of tasks—that are carried out interactively in group processes. Collaborative learning involves individual learning but is not reducible to it (see Nathan & Sawyer, this volume). 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 studied as a group process; research on 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 chapter.

CSCL developed in reaction to earlier attempts to use technology within education and to previous approaches to understand collaborative phenomena with traditional methods. The Learning Sciences have shifted from a narrow focus on individual learning to an incorporation of individual, group and community learning—and the evolution of CSCL has paralleled this movement.

The Historical 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 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 biennially. The CSCL conference proceedings have been a primary vehicle for publications in the field. Several journals have also played a role, including the *Journal of the Learning Sciences* and the *International Journal of Computer-Supported Collaborative Learning,* which started publishing in 2006. A CSCL book series published by Springer began then also.

From Artificial Intelligence to Collaboration Support

The field of CSCL can be contrasted with earlier approaches to using computers in education. Koschmann (1996) identified the following historical sequence of approaches: (a) computer-assisted instruction, (b) intelligent tutoring systems, (c) programming, (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—based on a cognitivist philosophy—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 developed software that responded to student actions based on occurrences of typical errors found in models of student problem solving. Intelligent tutoring systems are a prime example of AI, because they replicate the actions of a human tutor. This is still an active research area within the learning sciences (see Koedinger, this volume), but is limited to domains of knowledge where mental models can be algorithmically defined. It was natural that computer scientists interested in educational applications of computer technology would be attracted by the exciting promises of artificial intelligence (AI); researchers in AI and Education were influential in CSCL.

(c) The third use of computers in education began in the 1980s; it was epitomized by the teaching of the Logo programming language—as a training ground for logical thinking (Koschmann, 1997). Logo programming 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 like functions, subroutines, loops, variables or recursion.

(d) CSCL represents the most recent use of computers in education. CSCL approaches explore how computers can bring students together to learn collaboratively in small groups and in learning communities. Motivated by social-constructivist and dialogical theories, these efforts provide and support opportunities for students to learn together by directed discourse that constructs shared knowledge.

Within CSCL, the focus is on learning through collaboration with other students rather than directly from the teacher. Therefore, the role of the computer shifts from supplying 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 a network of computers to provide a medium of communication. This may take the form of email, chat, discussion forums, videoconferencing, instant messaging, etc. CSCL systems typically offer a combination of several media and add special functionality to them.

Since the early days of CSCL, social media have become widely available and heavily used by students. They often offer media of communication for CSCL, but they are problematic. Commercially designed for non-educational applications, apps like Facebook and Twitter foster distraction, limited time on task and sharing of trivia, preconceptions, gossip, flaming, emotion, fake news, culture wars and stubborn personal opinions. They are not designed to support rich collaborative knowledge building, scientific investigation or the construction of insightful shared meaning. They lack the discipline-specific supports of CSCL systems, which may include teacher guidance,

relevant background knowledge, exploratory models, learning scaffolds, extended time-on-task or reflection and feedback components.

CSCL software environments provide various forms of pedagogical support for collaboration processes. These may be implemented with computational mechanisms, including AI techniques. They can offer alternative views on the ongoing student discussion and emerging shared information. They can supply feedback, possibly based on a model of group inquiry. They can encourage sociability by monitoring interaction patterns and offering contextualized information to students. In most cases, the role of the computer is secondary to the interpersonal collaboration process among the students (often guided by a teacher, tutor or mentor). The software is designed to support, not replace or distract from, these 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 have defined the evolution of the field of CSCL.

From Individuals to Interacting Groups

At about the time of the first CSCL conference in 1995, 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 capturing, 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 them in their temporal interactions (Enyedy & Stevens, this volume).

From Mental Representations to Interactional Meaning Making

The shift to studying processes at the group unit of analysis coincided with a focus on the community as the agent of situated learning (Engeström & Greeno, this volume; Lave, 1991) or collaborative knowledge building (Scardamalia & Bereiter, 1991; this volume). 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 consider what may be in the heads of individuals, because that does not capture the processes of *shared meaning making* that are going on within collaborative interactions.

Collaboration is primarily conceptualized as an activity of shared meaning construction. Meaning is not treated as an expression of mental representations of individual participants, but as an interactional achievement of the group. 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.

From Quantitative Comparisons to Micro Case Studies

To view 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 short periods of group interaction, rather than across longer periods between pre- and post-tests.

Ironically, 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 structured by the participants to display their understanding. That is the basis for successful collaboration. Researchers can take advantage of these displays (if 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 and adopted group practices.

Methodologies like conversation analysis (Sacks, 1992) or video analysis (Koschmann, Stahl & Zemel, 2005) based on ethnomethodology (Garfinkel, 1967) produce detailed case studies of collaborative meaning making (Chinn & Sherin, this volume; Enyedy & Stevens, this volume). 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 (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

Emerging New Conceptions of Learning

In the past, educational researchers treated learning as a purely psychological phenomenon. Learning was taken to have three essential features: First, it represents a response to and recording of experience. Second, learning is treated as a change that occurs over time. Finally, learning is seen as a process not available to direct inspection (Koschmann, 2002). 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.

Edwin Thorndike (1912), a founder of the traditional educational approach, 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 [page] two become visible, and so on, much that now requires personal instruction could be managed by [automated] print. (p. 165)

This quotation is notable in that it suggests that the central idea of computer-aided instruction long preceded the actual development of computers. 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 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 (Jonçich, 1968; Koschmann, 2011). Historically, research on educational technology has been tied to this tradition and represents a specialization within it (Cuban, 1986).

CSCL stands apart from more conventional approaches to doing educational research not only in terms of the types of technologies and instructional methods that it uses, but more fundamentally in its epistemological philosophy (theory of how knowledge is possible and what knowledge consists of). Research in education has traditionally rested upon a “Correspondence Theory of Truth.” Knowledge, in this regard, consists of

inventories of facts—propositions that are true by virtue of their observable correspondence to a fixed reality regardless of circumstances (David, 2016). Learning, under such an epistemological theory, entails the acquisition of true propositions. Embracing this view, Thorndike held that the first task for an educational science was to design reliable instruments for assessing a subject's knowledge, conceived of as acquired facts and propositions (Jonçich, 1968).

In situations of conjoint activity, such as collaborative learning, a different treatment of knowledge comes into play. Knowledge under these circumstances is not context-independent—just the opposite. What counts as knowledge is worked out within interaction between parties and is inextricably bound to the setting and circumstances in which they find themselves. What is taken to be known is evaluated in terms of mutual understanding and situational coherence. For this reason, philosophers refer to this as a "Coherence Theory of Truth" (Young, 2018). Rather than acquiring an inventory of decontextualized facts, collaborative learning under such a theory is a witnessable process of sense making or knowledge building by the group in the moment. To study sense making in the moment not only requires a different conceptualization of learning, but also a different set of methods than those employed previously in educational research.

Building on this view, the so-called "edifying philosophers" (Rorty, 1974)—James, Dewey, Wittgenstein and Heidegger—rejected the view of learning as an inaccessible event in which knowledge is inscribed in individual minds. CSCL—focused on collaborative learning—embraces this situated view of learning, thereby rejecting the tenets of traditional 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; Reckwitz, 2002) and dialogical theories of learning (e.g., Hicks, 1996; Wegerif, 2006) most directly subscribe 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 and knowledge within a community. Dialogical theories locate learning in the emergent development of meaning within social interaction. Taken together, they offer 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 have dramatically changed the ways we work, play, think, discuss and learn. No form of technology, however, no matter how cleverly designed or sophisticated, has the ability, by itself, to change practice. To create the possibility of an enhanced form of practice requires multifaceted forms of design, bringing in expertise, theories and practices from various disciplines: to address 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 by themselves cannot define new forms of practice but are instead constituted within practice. An environment for a desired form of educational practice becomes such through the organized actions of its inhabitants. Tools and artifacts are only tools and artifacts in terms of how they are oriented to and made relevant by participants in directed practice. Even activities are only rendered recognizable as such by how 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. Group participants routinely engage in coordinated activity and operate as if shared understanding was both possible and continually being achieved. A fundamental question, therefore, is: How is this *intersubjective* meaning making accomplished? 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 established and maintained has been taken up in a variety of specialized disciplines such as pragmatics (Sperber & Wilson, 1982), social psychology (Rommetveit, 1974), linguistic anthropology (Hanks, 1996), philosophy (Stahl, 2021, Investigation 18) and sociology (cf. Goffman, 1974), especially sociological research in the ethnomethodological tradition (Garfinkel, 1967; Heritage, 1984). The problem of intersubjectivity is particularly of 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 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, communication studies, organizational science and others.

CSCL research has both analytic and design components. Ethnomethodological 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. Technological 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 practices of meaning making. 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 desired group practices (Koschmann et al., 2005; Stahl, 2016).

CSCL must continue with its work of self-invention: introducing new sources of theory, presenting analyses of learner practice and designing technological artifacts guided 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 (2002) presented a programmatic description of CSCL in his keynote at the 2002 CSCL conference:

> 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 definition of CSCL as being concerned with the "practices of meaning making in the context of joint activity" can be understood in multiple ways. A traditional "cooperative" interpretation would focus on the individual mental efforts of participants in a group, applying social practices to construct their own personal meanings. However, in CSCL, we are concerned with group practices of meaning making, conducted through interactional processes and resulting in shared meanings. Meanings—such as the meanings of words, drawings, gestures, theories—are never fundamentally private; they are essentially forms of communication within groups or cultures and must be mutually understandable.

The aspect of collaborative learning hardest to comprehend is what may be called *intersubjective meaning making* (Suthers, 2006) or *group cognition* (Stahl, 2006; 2009, 2013, 2016, 2021). This is learning that is not merely carried out interactionally but is actually *constituted* out of the interactions between participants. Following Garfinkel, Koschmann et al. (2005) argued for the study of "member's methods" of meaning making: "how participants in such [instructional] settings actually go about *doing* learning." 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 pervasive within CSCL research. Even where interaction processes (rather than individual learning outcomes) are examined in detail, the analysis is often 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 and interpret those phenomena in their unique situations (Stahl, 2002). Coding is useful for comparing experimental cases, but not for analyzing sequential interactions.

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, 2016). Roschelle's early study designed software 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) argued that small groups are the most fruitful unit of study, 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 the interactions. 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 their communities. 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, p. 16). Small groups may learn by adopting social practices as their own group practices and then potentially appropriating them as individual skills of the group participants (Stahl, 2016).

Small groups should not be the only social granularity studied within CSCL. 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. It is important to research the intertwining of processes on the individual, small-group and community levels of analysis.

The study of the interactional accomplishment of intersubjective meaning making 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: How do cognitive phenomena take place trans-personally in group discourse? How is it possible for learning, traditionally conceived of as an individual cognitive function, to be distributed across people and artifacts? How can we understand knowledge as accomplished practice rather than as a mental substance or even as an individual's predisposition? The perspective of CSCL on these matters requires overcoming engrained ways of thinking about cognition in terms of individual minds.

The Analysis of Computer Support

In typical CSCL contexts, interactions among individuals are mediated by computer environments. The second half of Koschmann's programmatic definition of the domain of CSCL involves "the ways in which these practices [meaning making in the context of joint activity] are mediated through designed artifacts" (Koschmann, 2002, p. 18). 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. This means that the technology is designed specifically to mediate and encourage social acts that constitute group learning and may subsequently 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 do something for which it is not well suited. What characteristics of information technology can facilitate effective CSCL?

- Computational media can be reconfigurable. Representations are dynamic: it is possible 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 simply force it to replicate face-to-face interaction.

- Computational media can "turn communication into substance" (Dillenbourg, 2005). A record of activity, as well as digital products can be retained, replayed and repeatedly modified. We should explore the potential of the persistent record of interaction and collaboration as a resource (group memory) for intersubjective meaning making.
- Computational media can analyze the workspace state and interaction sequences they support. They can reconfigure themselves or generate prompts according to what takes place in the media. We should explore the potential of adaptive media as an influence on the course of intersubjective processes, and take advantage of their ability to prompt, analyze and selectively respond. Computational media supporting student groups can inform teachers in real time about how each group is progressing (learning analytics: Baker & Siemens, this volume).

Human communication and the use of representational resources for this communication is highly flexible: we cannot "fix" meanings or even specify communicative functions (Dwyer & Suthers, 2006). Informed by this fact, CSCL research should identify the unique advantages of computational media and explore how collaborators use these and how they influence the course of their meaning making. This would enable the design of technologies that offer collections of features through which groups can interactionally engage in learning with flexible forms of guidance.

The Multidisciplinarity of CSCL

Research in CSCL to date has generally followed three methodological traditions: (a) experimental studies, (b) descriptive case studies and (c) the design of new ways of instructing, some projects drawing on more than one approach.

(a) Following in a tradition which can be traced back to Thorndike (Koschmann, 2011, p. 6), many CSCL studies are set up as clinical trials in which an intervention is compared to a control condition in terms of one or more variables. Scores are generated using a measurement instrument or a coding procedure of some sort. These can then be pooled to control for individual variability and permit the making of statistical inferences. Such methods can be used to evaluate the effectiveness of the intervention, i.e. whether it works. This leaves, however, other questions open, such as, how is the intervention actually accomplished in any particular context and what meaning does the instructional activity hold for the participants.

(b) Studying how meaning is established intersubjectively in the moment, one must look beyond simple scores to the practical settings from which the scores were extracted. This entails using more descriptive and ethnographic methods borrowed from the social sciences (Koschmann, 2018). One cannot make generalized claims based on a case study, but such studies can provide useful insight into how an intervention works. Indeed, such situated studies may enable us to discover what the intervention is!

The foregoing considerations might suggest that we explore hybrid (Johnson & Onwuegbuzie, 2004) or multi-vocal (Suthers, et al., 2013) research methodologies. Experimental designs can continue to compare interventions, but the comparisons would be made in terms of micro-analyses of how the features of information technology influence and are 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).

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). When blending methods from different traditions, however, researchers must be mindful of possible differences in epistemological assumptions that are built into these traditions.

(c) Beyond the questions of whether collaborative learning works and how learning in settings of collaboration is accomplished is the question: How can we make collaborative learning *better*? Design has been central to CSCL research from the very beginning of the field. In our sister field of CSCW, the question of precisely how ethnographically based empirical research can inform design of technologies has been discussed at length (e.g., Button, Crabtree, Rouncefield & Tolmie, 2015). Design-Based Research (DBR) has been advanced as the primary means of accomplishing this in the Learning Sciences (see Barab, this volume). DBR draws upon the *iterative design* tradition. Driven by the dialectic between theory and informal observations while engaging stakeholders in the process, design-oriented researchers continuously improve artifacts intended to mediate learning and collaboration in cycles of design, testing, analysis and redesign. 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. While the results of prior experimental research may provide clues for initial design and clinical trials may be important to eventual evaluation of an innovation, iterative examination of the innovation-in-use is an essential component of DBR (Koschmann, Stahl & Zemel, 2005). This is because ethnographic and descriptive methods are most applicable to understanding how meaning-making is accomplished in the augmented learning situation.

A potential limitation of both experimental and descriptive methodologies should be noted. If we focus on finding examples of how members accomplish effective learning, we may miss examples of how they also fail to do so. To find that something is not there, we need to have an idea of what we are looking for. Common patterns found in successful learning episodes subsequently become the theoretical categories we look for elsewhere with analytic methods, and perhaps fail to find in instances of unsuccessful collaboration. Having identified where the successful methods were *not* applied, we can 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, and into what is normally taken for granted and invisible.

CSCL Research in the Future

Research in CSCL responds to multiple goals and constraints. The research community includes people from a variety of professional and disciplinary backgrounds and training. 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.

Sfard (1998) defined 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. Koschmann (2001) suggested that a third metaphor for learning could be found in Dewey's notion of transactional inquiry (Dewey & Bentley, 1991). For Dewey, inquiry becomes transactional when it considers the phenomenon under investigation, not detached from its environment, but rather in its full interconnectedness. Applying this idea to learning would require us to recognize that learning results in more than just a change to the individual, but is rather a transaction between that individual and the social and material environment in which that individual is situated, through which both are changed. Lipponen et al. (2004) proposed another candidate for a third metaphor based on Bereiter (2002) and Engeström (1987): the knowledge-creation metaphor, in which new knowledge objects or group practices are created in the world through collaboration. Both proposals gesture in the direction of a new treatment of learning, one built upon a different epistemology and one calling for a new set of research methods.

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. It is always important that researchers clearly identify the approach they are using, including its consistent theoretical and methodological framework.

A multi-vocal approach may be productive despite its tensions (Suthers, et al., 2013): the experimentalists may identify variables that affect general parameters of collaborative behavior; the ethnomethodologists may identify patterns of joint activity that are essential to meaning making; and designers may innovate to creatively adapt new technological possibilities. Experimentalists within CSCL may start to focus on the dependent variables that directly reflect the phenomena of interest to descriptive researchers (Fischer & Granoo, 1995); more ethnographically-oriented researchers, on the other hand, may look for *predictive* regularities in technology-mediated meaning making that can inform design; and designers may generate and assess promising new technology affordances in terms of the meaning-making activities or "group practices" (Stahl, 2016) 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 CSCL, supported by corresponding theoretical conceptualizations.

Having appropriated ideas, methods and functionality from cognate fields, the CSCL community may now construct new theories, methodologies and technologies specific to the task of analyzing group practices and intersubjective meaning making to support collaborative learning (Medina & Stahl, 2021; Stahl, 2021; Stahl & Hakkarainen 2021).

We have argued here that CSCL requires a focus on the meaning-making practices of collaborating groups and on the design of technological artifacts to mediate group interaction, rather than a primary concern with individual learning. While multiple theories, pedagogies, technologies and analysis methods may be necessary in response to the complexity of CSCL, we believe that those that are oriented to and focused on the intersubjective meaning making at the center of collaborative learning are particularly appropriate to CSCL research and practice, and set CSCL apart from the rest of the Learning Sciences.

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