Computer-supported Collaborative Learning and Conceptual Change

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Abstract: Students often have difficulties achieving conceptual change in both individual learning and collaborative learning environments. Although research in the fields of both conceptual change and collaborative learning are well documented, few studies examine the relations between computer support and collaborative conceptual change. This review addresses this issue and considers the potential of CSCL for promoting conceptual change. We first review the major findings in the fields of conceptual change and collaborative learning. We then review literature on CSCL and discuss why CSCL environments may help in overcoming barriers to collaborative conceptual change. Finally, implications are provided for future CSCL design.

Introduction

There is broad consensus on the potential for computer-supported learning environments, particularly computer-supported collaborative learning (CSCL) to improve students learning (Goldman-Segall & Maxwell, 2003; Suthers, 2006). Although much research has examined whether computer-supported activities or collaborative activities are related to learning, less attention has been paid to the issue of whether computer-supported activities can foster collaborative conceptual change. The purpose of this review is to explore specific ways in which computers may offer powerful support for collaborative conceptual change in scientific domains. There are four sections in this review with the major focus on the last two: conceptual change, collaborative conceptual change, computer-supported conceptual change, and computer-supported collaborative conceptual change. The first two sections briefly introduce some major findings regarding individual and collaborative conceptual change. The third section will discuss the relationships between computer-supported learning and conceptual change. The fourth section is the core of this review: how collaborative conceptual change may occur with the support of computer-based instruction. We will use both theoretical and empirical evidence to consider the potential effectiveness of CSCL environments in fostering conceptual change.

Conceptual Change Theories

Conceptual changes refer to a process by which learners build new ideas in the context of their existing understanding (diSessa, 2006). In science education, the ideal conceptual change involves students' shift from their initial preconceptions to scientific conceptions (i.e., scientific beliefs, ideas, or way of thinking). Conceptual change is a difficult and complex process (Chinn & Malhotra, 2002). There is a huge diversity of perspectives about basic issues in conceptual change. Posner and colleagues (Posner, Strike, Hewson, & Gertzog, 1982) proposed a highly influential theory of conceptual change, which regarded conceptual change as linear and radical. Alternatively, diSessa (1993) believes learning is a gradual and evolutionary change in the way learners reconstruct their ideas and conceptions. Carey (1991) considers conceptual change as a process of enrichment (a form of weak restructuring) and revision (a form of strong or radical restructuring) of prior knowledge and interpretative frameworks. Regardless of the different theoretical perspectives on conceptual change, the common underlying theme is to investigate ways to promote such change.

There are two major categories of perspectives: Piagetian perspectives and the social constructivist perspectives. The Piagetian perspectives on conceptual change stress the importance of recognizing knowledge discrepancy in learners' prior knowledge and dissatisfaction with existing knowledge. In addition, this line of research regards the conceptual change process as either knowledge assimilation or knowledge accommodation. The cognitive conflict approach to achieve conceptual change typically involves evaluating learners' existing knowledge, presenting conflicting information, and re-evaluating, leading to changes in learners' conceptions. Thus one essential strategy that Piagetian perspectives recommend to foster conceptual change is to confront students with discrepant data or events (Chinn, & Brewer, 1993; Driver, Guesne, & Tiberghien, 1985). However, empirical studies show that even cognitive discrepancies often do not lead to conceptual change. Nissani and Hoefler-Nissani (1992) presented a study in which even natural scientists were surprisingly resistant to shifting their conceptions despite contradictory data.

Alternatively, social constructivist theories view conceptual change via the lens of social contexts and take into account the distributed nature of cognition. They follow Vygotsky's argument (1978) that all higher psychological functions (e.g. perception, voluntary attention) have social origins. This line of research views conceptual change as occurring through social interactions such as collaborative learning. Research consistently demonstrates that tasks that require learners to engage in active, constructive and integrative tasks lead to best understanding (e.g., Chi, de Leeuw, Chiu & LaVancher, 1994; Goldman, 1997). Collaborative learning can provide affordances for such engagement (O'Donnell & O'Kelly, 1994). For example, Chinn, Anderson, and Waggoner (2000) demonstrated that students who engaged in more argumentation-related behaviors developed better understanding from peer discussion than individual learning. Duschl and Osborne (2002) suggested that argumentation can be prompted by providing access to multiple accounts of phenomena and evidence and with a context to foster dialogic activity. Stressing the need to consider affective and social factors, Pintrich, Marx, & Boyle (1993) challenged Posner et al's (1982 original conceptual change model), which they called "cold" change. Instead, they developed the notion of "hot" or *intentional* conceptual change. All in all, the social constructivist perspectives particularly point out the importance of social interactions in the process of conceptual change. In the next section, we will elucidate how conceptual change takes place in the collaborative learning environment.

Collaborative Conceptual Change

Social constructivists argue that knowledge develops through social negotiation. Their assumption is that engagement in discourse promotes learning (Rogoff, 1990). First, peer interactions may lead students to restructure their existing knowledge. Roschelle (1992) reports a study in which convergent conceptual change occurred when students collaboratively used a computer simulation - the Envisioning Machine (EM) to learn about two physical concepts: velocity and acceleration. In the EM study, students restructured their commonsense ideas, to make meaning of a scientific concept. Students referred to the concepts of velocity and acceleration as the "thin" and "thick" arrows and successfully shared the meaning of these concepts by iterative cycles of displaying, confirming, and repairing meanings. Secondly, peer interactions may stimulate the need for knowledge revision. Duschl and Osborne (2002) suggest that opportunities for discussion and argumentation aids students in considering and evaluating other perspectives and thus may help learners revise their original ideas. Scientific argumentation usually involves proposing, supporting, criticizing, evaluating, and refining ideas. Peer collaboration provides a rich environment for mutual discovery, reciprocal feedback, and frequent sharing of ideas. Crook (1994) pointed out three major cognitive benefits of peer collaboration: articulation, conflict, and co-construction. The discrepant ideas from peers may require students to explain or reflect on and then compare their original ideas with alternatives from their peers, thus leading to eventual conceptual change. Finally, peer interactions may encourage deep mental processing. According to Chinn and Brewer (1993), deep processing includes attending to contradictory information, attempting to make meaning of alternative ideas, looking for evidence to support or dispute a theory, establishing causal relations between the evidence and considering the validity of evidence. In collaborative learning, students have the tendency to convince others by providing evidence to support their own theories and ask for evidence for alternative theories.

In summary, peer interactions may contribute to conceptual change by arousing an awareness of the need for knowledge revision, initiating knowledge reconstruction, and encouraging deep processing. However, there is no guarantee that collaborative learning will be productive and successful (Dillenbourg, 1999; O'Donnell, & O'Kelly, 1994). Barron (2000) found that it is necessary to find ways to help students achieve common ground when facing novel problems and coordinate efforts in collaborative activities. CSCL environments have the potential to help make collaboration more effective.

Computer-supported Conceptual Change

Research has shown computers are particularly effective in fostering conceptual change because in these environments, students can engage with simulated phenomena and review their actions as they formulate and test alternative hypotheses, receive feedback, and reconcile the discrepancy between their ideas and the observations (e.g. Beichner, 1996; White, 1993; Zietsman, & Hewson, 1986). Beichner (1996) proposed that technology-based instructional approaches could allow for an examination of interactions and collisions that is more direct and obvious than with traditional laboratory methods. In his study, 368 introductory physics students in a variety of instructional settings used a video analysis software package - the *VideoGraph,* which allowed students to compare videos directly with synchronized, animated graphs and to measure slopes and areas on the graphs. The outcome of the post-instruction assessment of students' ability to interpret kinematics graphs shows that students using this software performed better than those taught via traditional instruction. Zietsman and Hewson (1986) investigated the effects of instruction using computer simulations along with conceptual change strategies. They showed that computer simulations may highlight when students' current conceptions are not adequate and thus promote conceptual change.

Computer-supported learning environments may facilitate students in developing their metacognitive capabilities. Computer technologies provide explicit cognitive models to help students' planning, monitoring, revising and reflecting. For example, ThinkerTools promoted students' metacognitive ability to plan, monitor and reflecting during scientific inquiry in addition to helping students learn physics concepts (White, 1993; White & Frederiksen, 2000). The ThinkerTools curriculum focuses on the development of metacognitive knowledge and skills needed to create and revise their theories through an instructional inquiry cycle consisting of a motivation phase, model evaluation phase, formalization phase, and transfer phase. It provides a set of interactive simulations and modeling tools for middle school students to develop understanding of physical theories as they engaged in conducting experiments, creating and evaluating models, and revising the theories. Once they finally select the best theories and causal models, they apply them to different real-world situations by predicting and explaining what would happen. The results show that the alternative representations and models embodied in ThinkerTools helped students develop conceptual models that they could apply to solve physics problems.

In summary, empirical evidence shows that computer-supported learning environments may promote conceptual change in two ways: first, they can help students realize discrepancies between their original ideas and alternative ideas; second, they may provide affordances for developing students' metacognitive skills, such as planning, self-regulating, and monitoring. The research reported in this section examined individual conceptual change. In the next section, we discuss the role of computer-based learning environments in collaborative conceptual change.

Computer-Supported Learning and Collaborative Conceptual Change

Little research has attempted to examine CSCL environments from the perspective of collaborative conceptual change and show how and why CSCL may foster such change. In this section we provide both theoretical and empirical evidence to address this issue. The framework of analysis in this section is based on the obstacles that normally occur in the process of collaborative conceptual change and how computers may have the potential to help students overcome these obstacles. The theoretical analysis may shed light on the implications of future design of CSCL tools for the purpose of promoting conceptual change. To address this issue, we will first present two empirical studies that aimed to directly examine the role that computer-supported instructions play in collaborative learning. Then obstacles that occur in collaborative conceptual change will be discussed. Finally, we will discuss the potentials of CSCL instruction in the process of conceptual change. In general, computers have been used in two ways to promote collaborative learning (Hmelo, 2006). First, simulation and modeling tools create a context for students to test their conceptions and this context can provide a focus for negotiation. Second, computer-based discussion spaces can scaffold student reasoning and collaboration and provide opportunities for students to students to articulate their thinking, compare perspectives, and reflect on their learning.

Empirical Evidence

There are some empirical evidence supporting the idea that CSCL can promote student learning and conceptual change, such as Roschelle's influential study of dyads working with the Envisioning Machine discussed earlier (Roschelle, 1992). This use of computers falls into the first category: the EM provides a context for students to negotiate meaning and test their conceptions. Recall that this study investigated a dyad's collaborative conceptual change using a computer simulation. Based on these findings, Roschelle conceptualized collaboration as a process that gradually leads dyads' individual understandings to converge. The computer served as a medium for the dyads to establish the common understanding, which is critical for achieving collaborative conceptual change. However, collaborative conceptual change should go beyond knowledge convergence. Another example is the Force and Motion Microworld (FMM), a suite of computer simulation programs developed by Tao and Gunstone (1999). They examined high school students' collaborative conceptual development in physics. The findings showed that the FMM programs provided students with many opportunities for co-construction of shared knowledge through asking students to carry out predict-observe-explain tasks. Although there was evidence that students built on each other's ideas and reached shared understanding, not all students sustained their conceptual change after instruction. Only those students who were cognitively engaged in the tasks and prepared to reflect on and reconstruct their conceptions did obtain eventual conceptual change

Scardamalia, Bereiter, and Lamon (1994) also provided empirical evidence for the positive relations between CSCL and conceptual change while students worked with CSILE. The CSILE environment falls into the second category of tools that elicit articulation of ideas and scaffold building collective understanding. CSILE provides a networked community database where students can discuss ideas and build knowledge. The students must label their discussion notes using prompts that describe the role of the note (e.g., I need to understand, My theory). A series of studies indicated that students gain deeper understanding and collaboratively construct knowledge while working in CSILE environments compared with traditional classrooms in the depth of learning and reflection, awareness of what they have learned or need to learn. Moreover, students also achieved individual learning outcomes on standardized tests in reading, language, and vocabulary.

Vosniadou and Kollias (2003) used a computer-supported environment, the Web Knowledge Forum (WebKF; a descendant of CSILE), in which dyads constructed a model of the internal heating system of an average Greek house and explored how such a system works. Each student was required to keep notes of cognitive, metacognitive, and communicative activities. The results showed significant pre-post differences in understanding how a hot water heating system works but did not show gains in knowledge about heat and temperature in general. Interestingly, they found considerable metacognitive activity in dyads' conversations. Therefore, they concluded that CSCL environments can be helpful in developing metacognitive and intentional learning skills.

These empirical studies point out the important role of computer-supported learning environment in students' collaborative activities. However, they did not show how and why these CSCL environments can lead to successful conceptual change. Questions like whether and how computer-supported learning environments can foster collaborative learning remain unanswered. Therefore, we need to pay more attention to the specific roles that computers can play in fostering collaborative conceptual change. Furthermore, both studies indicated that collaborative conceptual change is beyond convergence of knowledge. There are several conditions that need to be met to achieve collaborative conceptual change, and these are difficult to achieve in many collaborative learning environments with no computer support. In the following section, we will address these issues through a theoretical analysis.

Theoretical Analysis

To present a theoretical analysis on how computers may provide affordances for collaborative conceptual change, we will first examine obstacles that normally occur in students' collaboration. We then consider evidence that CSCL environments have the potential to overcome these obstacles to collaborative conceptual change.

Obstacles to Collaborative Conceptual Change

Collaborative learning is not always successful (Dillenbourg, 1999; O'Donnell & O'Kelly, 1994). There are several obstacles in collaborative learning that need to be overcome to achieve collaborative conceptual change. Instructional techniques should provide affordances for overcoming these obstacles and promoting effective collaboration. First, the quality of dialogue or discussion is always a concern in collaborative learning. Deep processing is critical for conceptual change (Chinn & Brewer, 1993). If collaborative learning fails to involve deep processing or higher order thinking, such as attending to contradictory information, attempting to make meaning of alternative ideas, looking for evidence to support or dispute a theory, establishing causal relations between the evidence and considering the validity of evidence, the collaborative discourse may fail to promote deep processing. Chinn and colleagues argued that students often fail to change their theories because they 1) hold beliefs that cannot be integrated with the theory, 2) believe that some of the evidence can be explained by other implausible causes, or 3) cannot use the data presented to create a model of the phenomena (Chinn & Brewer, 2001; Chinn & Malhotra, 2002). Unfortunately, these same problems often occur in exchanges between students. Without scaffolding, collaborative discussions may remain superficial. Hence, instructional tools are needed to support learner's collaborative engagement in deep processing. More specifically, tools should support collaborative discussion that leads to making arguments on the basis of evidence and establishing causal relations between the evidence and one's perspective.

Second, according to classical conceptual change theory, cognitive conflict is regarded as essential to initiate conceptual change. One would expect that in collaborative discussions, there would be greater opportunities for conflict. Even though conflicts between individual ideas do not necessarily arise in peer collaboration, it is important to help arouse the within individual cognitive conflict by engaging students into reflection and accommodation of previous knowledge. Some research found that students seldom directly disagree with each other when collaboratively working on a problem due to politeness. Often, students even resist collaborative learning to avoid conflicts that might occur. There are two possible reasons for why students ignore the conflicts in their collaborative activity: either they may not realize the existence of alternative conceptions or they tend to take perspectives using different criteria to justify their ideas. If it is the first case, tools are needed to make the dynamic nature of scientific concepts explicit to students; if it is the second case, then students need to learn how to take a stance on the basis of experimental data or evidence. On the other hand, even if students clearly see the conflicts, they may resist conceptual change because people have a strong tendency to keep their original ideas. For instance, Chinn and Brewer (1993) proposed seven possible responses to anomalous data, only one of which is the adaptation of the theory on the basis of observed data. This indicates that students make arbitrary decisions when accepting or rejecting a theory. In accordance, Trumper (1997) also found that students reacted differently to conceptual conflicts that did not lead to conceptual change when learning about the energy concept. Some failed to recognize the conflict; some recognized but avoided solution by passively relying on other peers; some resolved the conflict partially; and some resolved the conflict using alternative conceptions. Tao and Gunstone (1999) asserted that "conceptual conflicts did not always produce conceptual change. For conflicts to lead to change, students need to reflect on and reconstruct their conceptions" (p.870). All these findings indicate that it is necessary to provide tools to help students realize the existence of alternative perspectives or even, if it is necessary, deliberately create conflicts in students' discussion thus prompt conceptual change. As well, it is also essential to provide appropriate scaffolding to facilitate student to learn how to make a decision on either accepting or rejecting theories on the basis of evidence. Only by reflecting on evidence and accommodating one's original ideas can conceptual change occur.

Third, the epistemic goals are rarely addressed in the collaborative learning (Duschl, & Osborne, 2002). The epistemic goals include aspects of what, how and why we know. These goals are critical for intentional conceptual change (Pintrich et al., 1993). Duschl and Osborne (2002) proposed that to enhance students' abilities to set epistemic goals, the instructional tools should focus on "(1) how evidence is used in science for the construction of explanation, and (2) on the criteria used in science to evaluate the selection of evidence and the construction of explanations." (p. 40). In collaborative learning, the epistemic goals may prompt students to change their ideas in response to evidence provided by others in the group. In addition, without knowing how and why they are learning, the students might just collaborate to memorize knowledge that remains encapsulated in a school context rather than co-construct knowledge that can be transferred to other situations. Hence, the conceptual change does not really take place for the purpose of conceptual change is to help students change their everyday life thinking by applying the scientific knowledge to explain phenomena and understand the world.

In summary, there are three major obstacles to achieving collaborative conceptual change: absence of epistemic goals, low quality of discussion, and inadequate skills to deal with competing ideas, all of which are essential aspects in the process of collaborative conceptual change. If the computer-supported tools can provide affordances to deal with these obstacles, computers may contribute to fostering collaborative conceptual change.

How Computers Can Help Deal with These Obstacles

Theoretically, appropriately designed CSCL environments can be powerful tools for overcoming obstacles to collaborative conceptual change by improving the quality of discussion, and providing scaffolding to facilitate student collaboration and working with alternative ideas, and making the epistemic goals explicit.

Improve the quality of discussion. Computers can mediate the collaborative discussion by focusing the discussion on the joint task and inspire deep processing. The computer screen offers highly shared focused objects for reflection and discussion. Students can avoid ambiguous language through images on the screen and establish common attention to referents within the discussion as occurred in Roschelle (1992) and Hmelo-Silver (2003). In addition, they can also test out alternative views. Hmelo-Silver (2003) conducted a study to examine how students constructed a joint problem-space. Groups of students were asked to design a clinical trial to test a cancer drug using the computer-based modeling tool, the OncoTCAP clinical trial wizard. In accord to Roschelle's findings, she found that even though direct conflicts rarely occurred in the group collaboration, students did tend to modify and refine their knowledge with the facilitation of the tools, which indicated that the collaborative activities within the computer-supported environment did help students realize the need to modify their knowledge base. Clements and

Nastasi (1988) found significant group differences among groups of students using Logo for conflict resolution, rule determination, and self-directed work. They suggested that it is the computer-assisted learning environments (e.g., simulation and word processing) that are likely to produce a greater frequency of quality interactions. However, it is possible that different software encourages different types of interactions amongst students (Crook, 1990). Wild (1995) investigated the verbal interactions of 12 students (9-10 yrs old) in four collaborative groups using simulation and word processing software. The simulation task involved the use of Terra Australis; students were given specific roles, encouraged to help each other and to make group decisions. The word processing task was to produce a combined report of the sailing adventure experienced while using Terra Australis. The results indicated that students' talk was more cognitively oriented when working with simulation software than when using the word processing.

King (1991) observed verbal interaction and problem solving behavior of small collaborative peer groups working on computer-based tasks. She found that successful groups engaged in more task talk than social talk. They ask more task-related questions, which were more strategic, and obtained higher elaboration scores than unsuccessful groups. Her study demonstrated that guided peer questioning in the computer-supported learning environment promote high quality peer interactions. Kozma (2000) concluded that computer-based technology can help collaborative interactions by providing symbolic elements and engaging students in focused inquiry that involves authentic scientific tasks. The combination of symbolic representations and inquiry activities enables and constrains the range of meanings by discourse, such that students can build on each other's ideas and intentions, draw new ideas into a common frame of meaning, and repair discrepancies.

In a follow-up to Roschelle's (1992) earlier study, Teasley and Roschelle (1993) examined how the EM simulation supported collaborative learning and thinking. In particular, the simulation provided a context that helped dyads successfully construct a joint problem space and share knowledge in the domain of Newtonian physics. They argued that the EM activity drew the emphasis away from the computer software per se and on to the quality of the dialogue. This study provided good evidence that dyads (15-year-olds) constructed a rich shared understanding of velocity and acceleration during a 45 min session using the EM. During that time, the dyads produced a lot of deep processing, such as exchanging ideas and explaining to each other, testing one's and each other's ideas in the simulation, making respectful changes judging by the validity of evidence.

In addition to deep processing, the quality of collaborative discourse largely depends on how much valid explanation, elaboration and argument is involved and how theories are evaluated. Webb (1989) conducted a meta-analysis which showed that the success of collaborative problem solving and learning depends largely on the level of elaboration of the information exchanged between the collaborating students. She concluded that group work with computers was beneficial and it was possible to design group-learning settings that benefited most students. Because computer-based simulations allow students to test their ideas, they are likely to confront with the discrepancies between observations and their originally conceptions. Beyond that, it gives students a rich context for discussion in which they can exchange and negotiate alternative perspectives (e.g., Hmelo-Silver, 2003). Computer-based learning environments can provide opportunities for students to elaborate their ideas, provide explanations, gather evidence to support their ideas or reject other alternative ideas as well as scaffolding evidence-based reasoning. Such opportunities may foster students' ability to use data to evaluate theories. In CSCL learning environments, students may use computer-based tools to test alternative ideas and the collaborative discourse can help individuals deal with the discrepancies between their conceptions and the available data. This affordance was illustrated in the example of the EM simulation (Roschelle, 1992; Teasley & Roschelle, 1993). The dyads were able to test out whether their ideas were correct or need repair. It the result of the testing did not support, they needed to negotiate until there understandings converged. Testing ideas was the most frequently strategy used to start negotiation in the EM simulation activity.

Make metacognitive thinking visible. The notion of intentional conceptual change brings attention to the role of students' metacognitive skills (Pintrich et al., 1993). Metacognition is the awareness and understanding of one's self as a thinker. Experts and effective thinkers tend to pose alternatives for themselves and choose among them by reflecting and using evidence. In contrast, students attempt to either accept without questioning or ignore alternative views. Therefore, approaches need to be developed to increase students' metacognitive awareness.

Traditional collaborative learning environment can make students thinking visible, CSCL environment can make collaborative thinking visible and can provide explicit support for students to construct arguments, engage in negotiation, and explain conceptual understanding. Most importantly, the techniques involved in CSCL environments afford helping student track their thinking process. The ThinkerTools is a good example of how computer-based environments may facilitate students to develop their metacognitive capability. White and Frederiksen (2000) report their findings of the instructional trials of the ThinkerTools Inquiry Curriculum in twelve urban classes in grades 7-9. Aiming at facilitating the development of metacognitive knowledge and skills that students need to create and revise their theories, the ThinkerTools incorporates a reflective process in which students evaluate their own and each other's research using a set of criteria that characterize good inquiry, such as reasoning carefully and collaborating well. They found that students who showed a clear understanding of the criteria produced higher quality investigations than those who showed less understanding. Their findings support that computer programs have the potential to introduce a metacognitive language to facilitate students' reflective explorations of their work in classroom conversations. Such metacognitive process may foster collaborative conceptual change by arousing an awareness of the need for revision of knowledge, initiating knowledge reconstruction, and encouraging deep processing.

In CSCL environments, electronic discussions provide affordances for students to engage in collaborative reflection. In a face-to-face classroom environment, the discussion might only benefit the few students who participate. The electronic environment allows universal participation. In addition, students have equal opportunities to respond to each other and engage in meaning making (Suthers, 2006). The electronic record is persistent and enables students to reflect on their own thinking as well as alternative ideas raised by other peer students. The CSCL environments can promote awareness of strategies for thinking by engaging the students in activities that require reflection. Students can keep and share a "thinking log" where they write down the thinking they employ in learning. As students share their entries, they gain an awareness of alternatives to their own processes. Activities like these, that require students to make the invisible work of thinking visible and explicit, help all students to visualize their thinking and alternative ideas. Hence, more purposeful, flexible, and reflective thinking is the result as the presence of other alternative perspectives available, which may prompt the process of conceptual change. Goldman, Duschl, Ellenbogen, Williams, and Tzou (2003) asserted that computer-based instruction might make thinking visible. They presented an example electronic environment, the Knowledge Forum (KF), which afforded to model the processes of coordination, construction, and evaluation to the students. Goldman et al (2003) found within the context of SEPIA project, which aims to promote scientific reasoning and communication, the KF entries "extremely valuable for taking the pulse of students' scientific thinking and argumentation approaches" (p. 278). They further implicated that there were some pragmatic constrains since the real application of the KF was somewhat different from what the creators intended. For example, the students only had time to make their own thinking visible but did not examine the entries of other students'. Another example CSCL environment is the KIE environment (the Knowledge-Learning Environment, the previous version of WISE). In the KIE, the SenseMaker tool makes it possible to help students see their thinking process when presenting argumentation (Bell & Davis, 2000). The SenseMaker helps students figure out the relationships between a numbers of Web resources by asking students to organize the information into categories and use them as evidence to make an argument. The Mildred tool in the KIE software provides conceptual and strategic hints to scaffold students' thinking. All these tools facilitate students to see their own thinking (Bell & Davis, 2000). Both KF and KIE illustrated that the CSCL environments have the potential to make students' thinking visible and enhance their metacognitive strategies.

Develop strategies to discover and resolve conceptual conflicts. Students have difficulties dealing with conflicts and need help realizing that there are competing conceptual explanations for phenomena. Sometimes it is even necessary to deliberately create conflicting perspectives so that students have chances to learn how to develop an effective argument in the collaborative work. For instance, in the KIE learning environment, students are asked to take one side of two conflicting hypotheses for the propagation of light. In this way, students need to explore sufficient experimental evidence to support the stance they take (Davis & Linn, 2000; Linn, 2000). Thus, the KIE software provides scaffolds for students to first realize the conflicting nature of scientific learning and to secondly learn how to resolve the conflicts by integrating alternative concepts. Although collaboration offers opportunities for conceptual conflicts to occur, when facing with such conflicts, students fail to reflect on why such conflicts exist and either ignore the conflicts or simply accept it without any support of evidence. Without such reflection, conceptual change is unlikely however collaborative learning settings may be more likely to promote such reflections as students compare their understandings and negotiate meaning.

CSCL environments can provide scaffolding to promote effective ways of dealing with conceptual conflicts. Student-initiated hypothesis generation is a central process in many computer-based learning environments and can help students to construct argument and produce conceptual conflicts. Computer-mediated communication offers the opportunities to structure learners' discourse in productive ways. Scaffolding and scripted collaboration can be operationalized by cues inserted into messages to help structure students' online discourse in productive ways. Weinberger, Fisher, and Mandl (2004) conducted a study investigating the effects of scripts on knowledge convergence in a computer-mediated communication learning environment. Each group of three learners was randomly assigned to one of the four experimental conditions in a 2 × 2 factorial design involving two factors: social scripts and epistemic scripts. Each group was asked to jointly prepare analyses for three case problems via web-based discussion boards. Two of the four conditions had the collaboration scripts implemented in the form of prompts inserted into the text windows of web-based discussion boards. The epistemic scripts supported the learners with their learning tasks by providing shared focus on the task, and the social scripts supported students to interact with each other by guiding them to share and contribute individual knowledge resources. The results showed that learners supported with epistemic scripts were highly convergent regarding focused knowledge during the collaborative phase but strongly impeded outcome convergence, the social script only slightly improved process convergence. These results indicated that different scripts in the computer-mediated environments may produce differential effects on knowledge convergence in collaborative learning.

A number of software environments that we have described involve scaffolding and scripts for argument construction including KIE (Davis & Linn, 2000; Linn, 2000), CSILE (Scardamalia & Bereiter, 1992), the Multimedia Forum Kiosk (Hoadley, Hsi, & Berman, 1995), Belvedere (Cavalli-Sforza, Weiner, & Lesgold, 1994). Grounded in research that has demonstrated the importance of argumentation in the process of conceptual change, all these tools aim to scaffold the development of students' argumentation and reasoning. KIE is a web-based environment that allows students to develop argument and use different sources of evidence to support their argument. CSILE is a communal database for building, articulating, and organizing knowledge. It facilitates students to set up hypothesis, search for knowledge and information to generate explanation and arguments to validate of falsify initial ideas. The Multimedia Forum Kiosk is an environment for discussion that makes use of multimedia for socially relevant representations, which allows the user to internalize and learn from the community knowledge base, and to construct knowledge by synthesizing new ideas. Belvedere is designed to support problem-based collaborative activities with evidence and concept maps. It has been assumed in all these computer-supported learning software that by laying out the relationships between evidence and arguments, students learn how to meet the needs to strengthen an argument.

Implications

To this point, we have discussed how computer-supported environments may promote conceptual change in the collaborative learning environment. We propose several implications for the design of CSCL environments to promote collaborative conceptual change. First, the focus of this review indicated three features of CSCL environments that may afford successful collaborative conceptual change. Designers should make efforts to include these features when designing a learning environment: scaffolds to improve the quality of collaborative discourse, make metacognitive thinking visible, and promote strategies to discover and resolve conceptual conflicts.

Second, it is critical to investigate and build on students' prior knowledge. In addition, it is also important to make the students themselves become aware of what preconceptions they hold. Bringing authentic problems or activities into the computer-supported learning environment may help fulfill this purpose. In this way, students have cues to activate their prior knowledge and connect it to current learning. However, the prior knowledge could either promote or impede the process of conceptual change (Pintrich et al., 1993). CSCL environments should give dynamic feedback to help students change their conceptions. One of the most importance strategies is to support students in generating alternative hypotheses, for example by providing the basic structure of a hypothesis as in BGuile (Reiser et al., 2003) which provides scaffolds for scientific inquiry in the domain of evolution. In addition, students' alternative perspectives are developed from experience and shaped by a socially constructed commonsense ways to describe and explain the world. CSCL environments need to include authentic activities and real world problems to connect to learners experiences.

Finally, as Goldman et al (2003) discovered that sometimes the CSCL tools are used differently from what the designers intend to. Therefore, much research needs to be done to investigate how to make full use of the designed tools and the range of more or less productive ways in which they can appropriated. CSCL tools themselves are not enough to promote collaborative conceptual change. Designers of CSCL environments need to consider the bigger context of how the tools will be used, the curriculum they will be used with, the participant structures, and the professional development for teachers who plan to use such environments.

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