Supports in CSCL

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Abstract: This study examined how technology supports collaborative learning in Computer-Supported Collaborative Learning (CSCL). Empirical CSCL studies published between 2005-2008 were selected from seven leading journals of the field and analyzed in terms of their technology supports. Analyses showed that communication technologies were most popular with asynchronous collaboration being the dominant mode of interaction. Although CSCL was predominantly supported by communication tools, diverse types of additional technologies (e.g., representational tool, simulations) were used to support both face-to-face and distributed collaboration. Technology supports varied depending on the educational levels, domains, and pedagogical approaches of the learning environments. Based on these analyses, we discuss five distinct ways that technology can support collaborative learning.

Introduction
Collaboration stimulates constructive processing, elaboration of knowledge and collaborative and social knowledge construction (Hmelo-Silver, 2009; eong & Chi, 2007). During collaboration, learners can learn from others, pool their resources toward a common goal, and come up with a solution that might not have been possible alone. For these reasons, collaborative learning, although it is not a panacea, is often considered to be one of the most effective forms of learning (Chi, 2009; Cohen, 1999; Scardamalia, 2002; Webb & alinscar, 1996). Although computers and other technologies were initially used to support individual learning (Lajoie, 2000; Reiser, 2001), the development of networked technologies prompted the emergence of Computer-Supported Collaborative Learning (CSCL). CSCL aims to provide technology supports for collaborative learning and has been considered to be one of the most promising applications of modern information and communication technology toward the improvement of teaching and learning (Lehtinen, Hakkarainen, Lipponen, Rahikainen, & Muukkonen, 1999; Stahl, Koschmann, & Suthers, 2006).

Although computers and digital technologies are actively used to support collaborative learning in CSCL, we do not understand exactly what kinds of technologies are used for this goal and how they support collaboration. In order to characterize the nature of supports computers provide for collaborative learning, researchers have used terms such as collaboration around versus through computers (Lehtinen, et al., 1999) or technology as a medium versus constraint (Suthers, 2006). These notions refer to the different ways that technology support collaborative learning. Metaphors such as “through” or “medium” refer to the role of technology as an enabler of communication, whereas the notion of collaboration “around” computers refers to their role as an object (i.e., contents) of collaboration (e.g., students discussing the contents of simulation). Technology as a “constraint” refers to its role to impose certain constraints on the interactive learning process (e.g., collaboration scripts). Given the proliferation of technologies and diverse ways that they are used to support learning and other human activities, there is a need to examine more systematically exactly how technologies support collaborative learning. Such an examination will not only help us to develop more accurate understanding about the role of technology support in CSCL but also to guide the efforts of the designers and instructors when they design and implement CSCL applications. The current study is a part of a larger project that attempts a comprehensive examination of CSCL research based on a content meta-analysis of recent CSCL investigations (eong & Hmelo-Silver, 2010a, 2010b, & 2011). In this paper, we focus on the nature of the support technologies provide for collaborative learning in CSCL and how it varied across educational levels, learning domains, and pedagogical approaches embodied in the learning environments.

Method

Journal Selection
Seven journals were selected for this study (1) International Journal of Computer-Supported Collaborative Learning (iJCSCL) (2) Journal of the Learning Sciences: (3) Learning and Instruction, (4) Computers and Education, (5) Journal of Computer-Assisted Learning (JCAL), (6) International Journal of Artificial Intelligence in Education, and (7) Computers in Human Behavior. The journals were selected based on a survey of 16 CSCL community leaders (e.g., CSCL committee of ICLS and the editorial board members of iJCSCL). These are all peer-reviewed journals published by well-known publishers with international author- and readership. Articles published during 2005-2008 period in these journals, that is, four years of publication and three years of publication in the case of iJCSCL were examined in the study.
Paper Selection

Excluding non-research articles (e.g., editorials), 1,222 articles were published in the seven journals during the 2005-2008 period. We screened them to identify empirical CSCL research papers. Research meant that learners learned collaboratively using technological tools. Learning needed to be collaborative, but as long as parts of the learning process involved interaction (e.g., collaborative discussion after individual study), it was considered collaborative. Collaboration was broadly defined, so that interaction with computerized agents, intelligent system, or other types of indirect interaction such as interaction via persistent artifacts (Suthers, Dwyer, Medina, & Vatrapu, 2010) was included. The focus was on peer collaboration. Student-teacher interactions were excluded unless peer collaboration was included. The technologies applied did not necessarily have to be so-called collaboration technology such as e-mails or discussion boards, but needed to be specific. Studies that examined social and technical issues were included if they were studied in relation to CSCL.

Analyses were restricted to empirical papers where primary data collection and analysis were carried out so as to focus on CSCL technologies that are actually implemented and researched.

The selection process proceeded in two stages. First, initial selection of empirical CSCL papers was conducted based on title and abstract of the paper. At this stage, we were as inclusive as possible so as not to miss any potential CSCL papers. This initial screening was verified at the coding stage so that final eligibility judgment was made based on a more comprehensive examination of the paper. The selection and coding process is not yet complete. This paper reports on preliminary results based on 28 papers currently in the coding pool.

Content Analysis

A combination of inductive and deductive approaches was used to develop coding categories. Codes were initially developed based on a combination of several top-down schemes (e.g., categories drawn from the submission descriptors of the 2005 CSCL conference) and then later refined inductively.

Technology

Technology refers to the technologies used to assist learning and consisted of the following 15 categories: (1) E-mails, (2) Discussion boards (including Knowledge Forum), (3) Chat, (4) Video-conferencing, (5) Mobile (e.g., phones, laptops, or other wireless devices), (6) Multi- or hyper-media (e.g., streaming videos), (7) Internet (e.g., websites, blogs), (8) Wiki, (9) Virtual reality (VR), (10) Multi-user virtual reality environments (MUVE), (11) Games, (12) Simulations, (13) Representational tools (e.g., concept maps, diagrams, or other visualization tools), (14) Intelligent System (e.g., simulated agents, Intelligent Tutoring Systems), (15) Others (e.g., hardware, generic software, or other miscellaneous technologies that did not fit into the preceding categories).

There was considerable variance in how researchers described their technology. The same technology was described with different names (e.g., discussion boards versus conferencing system) and/or at different granularity (e.g., generic description versus detailed description of hardware specifications). Because the focus of the current analysis was to identify technologies at a level where learners interact with them, technical aspects of the implementation (e.g., servers, system architectures, SCORM standards, etc.) were not coded unless directly used to support learning or collaboration. As for the Internet/web, it was coded as a separate technology when its contents (e.g., information on specific websites) were used for learning, but not when used as a medium of communication (e.g., e-mails) or as a delivery system (e.g., online course management software). Integrated system or learning environments such as e-learning platforms (e.g., WebCT, Moodle) were coded for their individual technologies, but complementary (e.g., tutorials are offered to students to help them use the tool better) or irrelevant technologies (e.g., technologies that may be part of the environment but irrelevant to the study) were not coded separately. When a technology could be categorized in more than one ways (e.g., a MUVE game can be coded either in the MUVE or game category), the dominant aspect of the technology was selected based on the research contexts and study questions.

Collaboration

Collaboration refers to the types of interaction among learners in CSCL environment and consisted of the following three types: (1) Mediated face-to-face, (2) Synchronous distributed, and (3) Asynchronous distributed. Mediated face-to-face collaboration refers to co-located and synchronous interaction supported by technology (e.g., collaboration around a computer simulation), which is different from more traditional unmediated face-to-face collaboration. Distributed collaboration refers to collaboration among distributed learners and can be either synchronous or asynchronous.

Educational Levels

Educational levels refer to the level of student learning examined in the study and consisted of the following three levels: (1) K-12 for primary and secondary education, (2) Higher education (i.e., undergraduate and graduate education), and (3) Other (e.g., professional training, life-long learning, learning networks outside of...
technology was communication technology that was used in more than half of the studies (59). Of these, research. The relative frequencies of CSCL technologies are shown in Figure 1. The most dominant CSCL (61) of them used a single technology, but the rest examined multiple, up to seven, technologies in their study. The mean number of technologies used in a study was 1.68 as studies often used multiple technologies. Most studies were conducted in secondary schools or other contexts. This coding was also applied to laboratory tasks if domains can be identified (e.g., science or educational problem solving in laboratory). When domain-independent knowledge or skills were learned in specific content domains (e.g., argumentation/writing about genetically modified food), we coded the content domain (e.g., science). When students learned about cross-disciplinary subjects (e.g., science communications, information technology in education), we coded them into one of the existing domains that best characterize them, but if they did not fit into existing domains, we coded them as other. Other domains also included hard-to-categorize domains, domain-independent learning (e.g., study skills), and unclear cases (e.g., university orientation).

Pedagogical Approaches
Pedagogical approaches refer to the instructional strategies used by teachers and reflect their beliefs about how learning occurs and how to promote it. Pedagogical approaches were coded into the following categories: (1) Traditional instructions (e.g., lectures), (2) Distance learning (e.g., learning in online courses, blended courses, learning networks, mobile learning), (3) Case-based instruction, (4) Problem solving, (5) Project/Problem-based learning (PB), (6) Design-based learning, (7) Hands-on/Active learning, (8) Inquiry (e.g., modeling, progressive Inquiry), (8) Game, (10) Collaboration, and (11) Other (e.g., informal learning, life-long learning, etc.). We distinguish problem- or project-based learning from problem solving as a pedagogical approach because in the former, problems are used as a context where students figure out what they need to know as they solve the problems (e.g., learning human physiology in the context of diagnosing disease by MacLeod, 2005) whereas in the latter, problems are more clear-cut, where learners apply and practice what they have learned previously (e.g., mathematical word problems by White, 2006). Although all papers used some kinds of collaboration in this study, it was not always the main feature of the pedagogy. Collaboration was coded as pedagogy when it was used as one of the main instructional features and can include (a) discussion, (b) argumentation, (c) role/scripted, (d) other miscellaneous collaboration (e.g., jigsaw, networked learning communities, wiki, or other unspecified group activities).

Although pedagogy is typically used to describe the teaching activities orchestrated in classroom settings, laboratory tasks can also embody certain pedagogical principles (e.g., study of argumentation in the laboratory). We thus coded pedagogical approaches of the CSCL investigations regardless of the study settings, but if underlying pedagogical approaches cannot be identified, it was assigned to other category. Different pedagogical approaches were often incorporated in one CSCL application or environment. For example, distance learning courses were often implemented with regular online conferences or topic discussions (Hewitt & Brett, 2007). Problem-based learning was also implemented with script/role assignments (White, 2006). Instead of coding one overarching pedagogical approach, we coded all the salient instructional strategies used in the study.

In all coding categories, multiple codes were allowed. For example, when a study compared effects of different collaboration conditions (e.g., shared wireless laptop vs. shared workspace as in MacLeod, 2005) or when several different technologies were implemented together in an environment (e.g., chat and representational tool as in Lund, Molinari, Scourne, & Baker, 2007), the study received multiple codes for each corresponding dimensions. Cohen’s Kappa for the 20 of the coded papers was all above .75 in all coding categories.

Results

Technology
The mean number of technologies used in a study was 1.68 as studies often used multiple technologies. Most (61%) of them used a single technology, but the rest examined multiple, up to seven, technologies in their research. The relative frequencies of CSCL technologies are shown in Figure 1. The most dominant CSCL technology was communication technology that was used in more than half of the studies (59%). Of these,
discussion boards were most frequent, being used in more than a third of the studies (39%), followed by chat (23%), e-mail (10%), and video-conferencing (6%). After the communication technology, the next frequent was other technology (28%), followed by the Internet/Web (14%), representational tools (13%), simulations (8%), multi/hyper-media and intelligent systems (each 6%), wiki (5%), mobiles (4%) and VR (4%), games (2%), and MUVE (1%).

Figure 1. Technologies used in CSCL investigations.

Unexpectedly, a lot of the technologies fell in the other technology category (28%). A closer examination of the other category showed that it included diverse technologies such as peer assessment systems (Cho Schunn, 2007), shared workspaces (Hwang, Chen, Hsu, 2006), application/file/data sharing, and tools to support specific aspects of collaborative learning such as meta-cognitive and/or regulation tools (Manlove, Lazonder, de Jong, 2006). It also included commercial software as students were asked to use word processors or text editors to compose messages for posting or as a reflection tool (Wang, 2005) and hardware and/or physical environments as physical layout of the classrooms or specific hardware (e.g., shared display) was part of an innovative learning environment (e.g., Dorf Belcher, 2005 Liu Kao, 2007). The large proportion of other technology category suggests that our understanding (and coding categories) of the major CSCL technologies may have been biased toward the technologies that received more attention in the research literature, and yet researchers were not only developing and using new tools (e.g., group meta-cognitive tools) but also using common tools in unconventional ways. Such diversity and ingenuity in tool used was also evident in other categories. The Internet/web technology was used in a number of different ways in CSCL. Students used web-based learning platform (e.g., Bartholome, Stahl, &ieschl, Bromme, 2006), used it as information resources (Lee, 2005), or constructed web pages or built communities as part of their learning activities (Turvey, 2006). Representational tools were often tools that allow graphical representations such as SenseMaker (Enyedy Hoadley, 2006), but some of them were specifically designed to support certain collaborative activities (e.g., argumentation Mirza, Tartas, &erret-Clemont, de ietro, 2007).

Learners in CSCL environments engaged in distributed asynchronous collaboration most frequently (56% of studies), followed by synchronous (36%) and mediated face-to-face collaboration (29%). Although the majority of the studies (80%) supported one type of collaboration, the rest (20%) supported more than one type of collaboration (e.g., Ellis, Goodyear, Rossier, O'Hara, Veermans Cesareni, 2005).

How did technologies support collaborative learning? Because studies often supported multiple types of collaboration, we focused on the studies that supported one type of collaboration only (206) for this analysis and examined how each collaboration type was supported by technologies. As for the synchronous collaboration, not surprisingly, it was mostly supported by chat (58%) and video-conferencing (16%) but also by representational tools (21%) and other technologies (26%) such as virtual agents, (Holmes, 2007) or application sharing (Ertl, Kopp, Mandl, 2008). As for the asynchronous collaboration, it was largely supported by communication technologies such as discussion boards (69%) and e-mail (8%), as well as by the Internet/Web (17%) and other technology (20%). Examples of other technology included peer review/evaluation system (Cho Schunn, 2007), database (Kali, 2006), or other miscellaneous technologies. Mediated face-to-face collaboration was supported mostly by non-communication technologies such as other technology (30%), simulations (19%), and hyper/multi-media (18%). They involved collaboration “around” computer (e.g., discussing a simulation while sharing the computer screen), “about” computers (e.g., collaborative programming in groups), or “with” computers (e.g., DAs supplementing face-to-face interaction). In an example of mediated face-to-face with computers, students engaged in face-to-face collaboration each with their
own handheld device (White, 2006). The task was divided so that each student carried out a different portion of the task and the changes that individual students made with his or her handhelds were propagated to other members’ handhelds. In this case, the handhelds allowed learners to work on different parts of the problem simultaneously and yet be in sync with other members’ progress.

**Educational Levels**

The majority of the CSCL learners reported were in higher education (60%), followed by K-12 (34%) and other (8%). CSCL technology supports differed across educational levels. Communication technology, for example, was used 65% in the higher education, but only 50% in K-12 and 46% in other levels. There was also a difference in the kinds of communication tools used (see Figure 2a). Asynchronous communication tools (e.g., e-mails and discussion board) were more heavily used in higher and other education levels. For example, the discussion board was used in 24% of the K-12 studies, but 47% and 38% in higher education and other levels, respectively. On the other hand, synchronous tools were used equally frequently in K-12, so that chat tools were used 23% of the time in K-12 studies and 24% and 13% in higher education and other levels. Another difference between levels was the use of multiple communication technologies: the average number of communication technologies was 1.15 in K-12, 1.36 in higher education, and 1.55 in other level. Figure 2b also shows that K-12 also tends to rely more on non-communication technologies such as simulations and representational tools. It is unclear at this point whether this is related to the maturity of the K-12 learners or merely due to the fact that learners at K-12 level tend to spend more time together in schools, but it appears that the more advanced the learners were, the bigger the tendency to rely on communication technologies, especially asynchronous types.

![Figure 2. CSCL technological supports across educational levels.](image)

**Learning Domains**

CSCL technologies were used in a range of domains such as science/math (34%), professional (44%), literacy/history (13%), social science (9%) and other (9%). CSCL technology supports differed across domains. Table 1 presents the top five technologies used in different learning domains. This table shows that, although the use of **author** and other technologies was dominant in all domains, it was less so in science/math. Technologies such as simulations and representational tools played more important roles in science/math.

![Table 1. Top five technologies used in different learning domains.](image)

**Collaboration Pedagogies**

Not surprisingly, collaboration pedagogy was implemented most frequently (43%), followed by distance learning (19%), inquiry (10%), BL (9%), problem solving (8%), traditional instruction (8%), design-based learning (5%), other (5%), case-based instruction (4%), and active/hands-on learning (4%). Within collaboration pedagogy, generic discussion was most frequent (18%), followed by misc. collaboration (9%), scaffolding (6%), argumentation (6%), and roles/scripted collaboration (5%). Although the majority (84%) of the studies employed single pedagogical approach, some used more than one approach. It appears that most CSCL

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investigations were embedded in some kinds of innovative pedagogies. Traditional pedagogy was not frequent. In addition, distance learning which often rely on traditional lecture and can thus be quite passive was complemented with other pedagogical approaches half of the time in the studies analyzed in this paper. Still, it should be noted that inclusion of discussions or other activities may not necessarily ensure innovate teaching and learning, and care need to be taken to ensure that appropriate learning activities occur.

We also examine whether different technologies are associated with different pedagogical approaches. Due to space limitations, however, we restricted our analysis to six major technologies—the two most frequent communication technologies (i.e., discussion board and chat), other technology, Internet/web, representational tool, and simulation—and identified three key pedagogies associated with each technology (see Table 2). Analyses showed that, for example, although the discussion board was the dominant technology associated with almost all pedagogical approaches, it was associated more strongly with distance learning and collaboration pedagogy. On the other hand, the representational tools and simulations were strongly associated with pedagogical approaches such as inquiry, problem solving, active/hands-on approaches. These results suggest that different pedagogical approaches are likely to have different technological needs. Researchers and educators need to align technological affordances with the pedagogical needs of the curriculum. In addition, although other technology was not of the same kinds, but its strong association with some of the pedagogical approaches (e.g., active/hands-on, other, and case-based) suggests that these pedagogical approaches might have technological needs unarticulated and unmet by more established and well-known technologies.

Table 2. Key pedagogical approaches associated with six major technologies.

<table>
<thead>
<tr>
<th>Technologies \ Ranks</th>
<th>1</th>
<th>2</th>
<th>3</th>
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<tbody>
<tr>
<td>Discussion B</td>
<td>Distance L (69)</td>
<td>Collaboration (48)</td>
<td>Inquiry (40)</td>
</tr>
<tr>
<td>Chat</td>
<td>Distance L (35)</td>
<td>Problem-solving (32)</td>
<td>Collaboration (25)</td>
</tr>
<tr>
<td>Other</td>
<td>Active/Hands-on (60)</td>
<td>Other (40)</td>
<td>Case-Based, Traditional (36)</td>
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<tr>
<td>Internet/Web</td>
<td>Other (33)</td>
<td>Design-based (20)</td>
<td>Distance L (20)</td>
</tr>
<tr>
<td>Rep. Tool</td>
<td>Inquiry (28)</td>
<td>Problem-solving (23)</td>
<td>Design-based, Active (20)</td>
</tr>
<tr>
<td>Simulation</td>
<td>Active/Hands-on (40)</td>
<td>Inquiry (24)</td>
<td>Problem-solving (14)</td>
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*indicates a tie with the preceding technology.

**SCUSS ON**

This study investigated technology supports in CSCL. A content meta-analysis of CSCL research showed that communication technologies were most common with the dominant mode of collaboration being asynchronous interaction. Although CSCL was largely supported by communication technologies, diverse other technologies (e.g., representational tool, simulations) were used to support both face-to-face and distributed collaboration. Technology supports varied depending on the educational levels, learning domains, and pedagogical approaches embedded in the learning environments so that the role of communication technology was lessened in K-12 and science/math domains. Different pedagogical approaches also appeared to have different technological needs.

Although there are many different types of learning technologies, not all have adequate affordances for learning. The argument for learning technology is not about having students learn faster, but rather about helping them learn better. Likewise, although there are many ways that technologies support collaborative learning, they need to do more than making interaction possible. They need to enhance and facilitate processes of collaborative learning (Suthers, 2006). What are the processes of collaborative learning that current CSCL technology applications support? Integrating the results of the current analyses and earlier conceptualizations (e.g., Hmelo-Silver, 2010a; Lehtinen, et al., 1999; Suthers, 2006), we identify five distinct types of technology supports for collaborative learning in CSCL applications. First, technologies support collaborative learning by providing means of communication. Technologies such as discussion boards and chat tools make distributed collaboration possible as partners in remote locations can interact synchronously with the help from these tools (Annen, Erkens, Kanselaar, Aspers, 2007; Vizzcaino, 2005). Asynchronous technologies also allow learners to interact whenever and wherever they want (Kitsantas, Chow, 2007; Liu, 2007). These types of technologies play more important roles in certain contexts such as in distance learning, but are important in other contexts as well. Second, technologies facilitate collaboration by providing a focal point of interaction around which learners discuss, argue, and explain (Lehtinen, et al., 1999). This type of facilitation typically occurred in face-to-face collaboration, but can also happen in distributed interaction (Susser, 2006b). Third, learners do not always engage in productive interaction during collaborative learning. Technologies can be used to guide learners toward task-specific interactions by imposing structures and constraints on the interaction process (Dillenbourg, Hong, 2008; Suthers, 2006; Weinberger, Ertl, Fischer, Mandl, 2005). Fourth, technologies provide tools and resources to manage and control collaborative processes. Representational tools such as whiteboards and graphic tools complement communication processes by providing deictic cues and also make the interactive process explicit (Hwang, Chen, Hsu, 2006; Lai, Wu, 2006; Liu, 2007). They become the basis of negotiating shared meaning and common grounds during
interaction. The resulting artifacts, be they argumentation maps or Wikipedia pages, serve as a basis of shared knowledge and collective memory. Technology also makes it possible for members to share resources more easily (MacLeod, 2005). Although such supports are still possible in traditional modes of collaboration with pen and paper, technologies make these functions much more accessible to learners. Fifth, technologies support collaborative learning by making new forms of interaction possible. Traditionally, interaction meant direct person-to-person interaction. Communication technologies make it possible to interact through e-mails or chat, but they still mean direct person-to-person interaction. New forms of interaction are possible with technologies so that learners can now interact indirectly through Wikipedia pages, social navigational support (Lee, 2005; Recker, Walker, & Lawless, 2003), or peer feedback system (Cho & Schunn, 2007). Interaction with non-human agents can also be used to monitor and support human learning (Vizzcaino, 2005).

These five types of technology supports are not equally realized in CSCL research with some types of supports being more mature and prevalent than other type of supports. We also do not understand yet how different types of supports interact with learner characteristics (e.g., educational levels) and various aspects of learning environments (e.g., learning domains and pedagogical approaches). Much CSCL research has been driven by the technologies rather than learners’ needs and underlying learning mechanisms. With technological advances, additional ways to support collaborative learning will emerge. Whatever the future technologies might be, we should bear in mind that technological advances will benefit CSCL to the extent that they support core mechanisms of collaborative learning. Increased awareness and attention to the underlying learning mechanisms in addition to the technology itself will help the designers and instructors to design and implement more effective CSCL applications.

References


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