Technology Use in CSCL: A Content Meta-Analysis

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Abstract
This study examined technology use in Computer Support for Collaborative Learning (CSCL). A content meta-analysis of empirical CSCL research was carried out to address three research questions: (1) What kinds of technologies are being used in CSCL research, (2) What kinds of collaboration are supported, and (3) What are the contexts of technology supports (e.g., learning domains, educational levels, and pedagogical approaches)? Empirical CSCL studies were selected from seven leading journals of the field. Analyses of a random sample of these studies showed that CSCL applications typically embedded more than one technology in their environments with the most common technology being communication technology. Perhaps not surprisingly then, distributed collaboration was more frequently supported than face-to-face collaboration in CSCL applications. Analyses also showed that CSCL was carried out across a range of disciplines in a variety of pedagogical contexts. Based on the analyses, five different types of technological supports for collaborative learning are proposed.

1. Introduction
Collaboration stimulates elaboration of knowledge, social knowledge construction, and collective knowledge building [1-3]. 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 is often considered to be one of the most effective forms of learning [4-8]. Numerous attempts have been made to implement learning activities in the context of small group interactions [3, 9-12], and computers have been actively used in this process [13-15]. Although computers and other technologies were initially used to support individual learning [16-17], the development of networked technologies contributed to the emergence of Computer-Supported Collaborative Learning (CSCL). CSCL aims to provide technological 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 [18].

CSCL applications include a wide variety of applications. For example, interaction technologies such as e-mails or chat are used widely as they help learners to interact with distant partners, expanding the circle of people they can collaborate with. In addition, technologies that are not necessarily designed with collaboration in mind are also used actively in the field [18]. Computer simulations, for example, provide representational tools for scientific phenomena that can be difficult to perceive with the naked eyes. They can be used alone [19], but are also often used in small groups as students engage in the manipulation of variables, observe resulting outcomes, and construct explanations of the phenomena collaboratively [20-22].

In order to conceptualize different kinds of technological supports for collaborative learning, researchers have proposed contrasts such as collaboration around versus through computers [18] or technology as a medium versus technology as a constraint [23]. In the former contrast, the role of computers as communication device was contrasted with their role as an object (i.e., contents) of communication. In the latter, the role of computers as a communication device was contrasted with their role to impose constraints on the interactive learning process. Although these contrasts have been useful in describing the different ways computers are used to support collaborative learning, we have reached a point where a more sophisticated understanding is needed in order to better guide the efforts of the designers and instructors in CSCL. Rapid technological advancement is creating new forms of interaction daily. In addition, the success of a given technology is often critically dependent on the contexts in which they are implemented. The role of a given technology needs to be examined in the contexts of its implementation. The goal of this study is to systematically document different ways that
technologies are used to support collaborative learning in CSCL. In doing so, we also aim to understand the contexts of technology support such as learning domains, educational levels, and pedagogical approaches implemented in conjunction with the technology applications.

To achieve these goals, this study carried out a content meta-analysis. While meta-analysis is typically associated with verifying statistical power of empirical results, content meta-analysis focuses on conceptual aspects of the investigations. Recently, there have been several content meta-analyses in research areas related to CSCL [24-26]. For example, Hrastinski and Keller examined research approaches in educational technology. They examined 660 papers published in 4 journals in 5 year period (2000-2004) [24]. They found that the majority of the papers (68%) were empirical papers and most of them (87%) had explicit method section. About half of the empirical papers (51%) used quantitative methods, while 25% of the papers used qualitative method and 24% used mixed methodologies.

Hew, Kale, and Kim also conducted similar meta-analysis in the field of instructional technology with a focus on empirical articles [25]. They examined 340 articles published in 3 journals during 5 year period (2000-2004). They analyzed research topics, research methods, data collection methods and research settings. They found that the majority of the articles published in the area were media studies or psychological studies that examined psychological processes. Descriptive, correlational, experimental and quasi-experimental methods were the common research methods with survey/questionnaires as the most common data collection method. As for research setting, higher education was the most common setting.

In the field of e-learning, Shih, Feng, and Tsai attempted to identify important research trends and papers [26]. They used a combination of citation analysis and content analysis and examined 444 papers published in five journals from 2001 to 2005. They coded the research topics of these studies and then identified 16 highly cited papers based on citation frequency. They found that almost half of the articles on e-learning were on cognition in e-learning with the most published topics being (a) interactive learning (environment), (b) collaborative learning (as instructional approaches) and (c) perception and awareness (part of meta-cognition). Interestingly, the highly cited articles did not necessarily study the most frequently studied topics. The highly-cited articles addressed research topics such as instructional approaches, information processing, and motivation. These topics may not have been studied widely, but have had greater impact on subsequent research.

Similar content meta-analysis was carried out in this study to address the following research questions: (1) What kinds of technologies are used in CSCL research, (2) What kinds of collaboration are supported, and (3) What are the contexts of technology applications in terms of learning domains, educational levels, and pedagogical approaches?

2. Methods

2.1. Journal selection

In preparation for journal selection, we first surveyed the leaders of the field (i.e., the editorial board members of International Journal of Computer Supported Collaborative Learning (ijCSCL) and CSCL committee of the International Society of Learning Sciences). We provided a definition of CSCL to the community leaders and asked them to provide feedback. The resulting definition of CSCL based upon the feedback from 16 respondents was: “Computer-supported collaborative learning (CSCL) is an interdisciplinary research field that includes a branch of the learning sciences and educational technology research concerned with studying how people can learn together with the help of computers [27]. Research in CSCL focuses on learning as a cognitive and/or social process and studies learning designs, learning processes and pedagogic practices that support technology-mediated coordination, communication collaborative processes in communities of [28].”

We also asked the community leaders to nominate leading journals of the field. In addition to ijCSCL, the flagship journal of the CSCL community, there are numerous research journals where CSCL research has been published. We thus asked the leaders to name five journals other than ijCSCL and selected the following seven journals: (1) ijCSCL, (2) Journal of the Learning Sciences, (3) Learning and Instruction, (4) Computers and Education, (5) Journal of Computer Assisted Learning, (6) International Journal of Artificial Intelligence in Education, and (7) Computers in Human Behavior. They are all peer-reviewed journals published by well-known publishers with international authorship and readership.

2.2. Paper selection

From the papers published in the seven journals, we identified empirical CSCL research to be used for
the content meta-analysis. By *empirical*, we mean that the study collects and analyzes empirical data. Secondary data analysis, simulated results, theoretical papers and meta-analyses were not included. The data may have been collected as part of a larger project, but the analysis and finding had to be new. Papers that described the design process were included if they reported on empirical data. The only exception to this rule was methodology papers that described development of specific assessment tools or analysis methods.

By *CSCL* research, we refer to studies where students learned collaboratively with the help from computers or other technology tools. We define collaboration as small group peer collaboration, that is, collaboration among learners who are similar in knowledge and status. This means that studies that examine student-teacher interaction or whole class discussions were not included unless they included small group peer collaboration. Not all phases of learning needed to be collaborative, but at least parts of the learning should involve collaboration. The applied technologies do not necessarily have to be collaboration technology such as e-mails or discussion boards, but the technology needs to be specific. Studies that investigated general technology use were not included. Interaction with computerized agents were included if it involved learning, but interaction involving Intelligent Tutoring Systems was not included unless the system was used collaboratively. Studies about motivation or attitudes were included if they were studied in relation to learning.

Excluding non-research articles (e.g., editorials, book reviews, or obituaries), 868 articles published in the 2005-2007 period were screened, which means three years of publication (two years of publication in the case of *ijCSCL*). Although the final set of selected papers is subject to change with additional coding, the total numbers of selected papers is 175 at the moment. This means that 20% of the papers published in the seven journals during 2005-2007 were empirical investigations of CSCL.

### 2.3. 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), but then later refined bottom-up through multiple iterations of coding (see Hew et al., 2007 for a similar approaches for code development in content meta-analyses). In this paper, we report on the analyses carried out on a random sample of the papers (33 papers, 19% of the total number of CSCL papers; they were marked with * in the reference). Specific codes for each category are described below.

#### 2.3.1. Technology. Technology refers to the technologies used to assist learning. There were 16 categories: (1) E-mails, (2) Discussion boards (e.g., Knowledge Forum), (3) Chat, (4) Video-conferencing, (5) Mobile (e.g., mobile phones, laptops, or other mobile devices), (6) Multi-media (e.g., streaming videos), (7) Internet (e.g., websites, blogs), (8) Wiki, (9) Virtual reality, (10) Multi-user virtual reality environments (e.g., MOO/MUD/MUVE), (11) Game, (12) Simulations, (13) Representational tools (e.g., concept maps, diagrams, or visualization tools), (14) Intelligent System (e.g., simulated agents, Intelligent Tutoring Systems), (15) Others (e.g., any technology that did not fit into the prior categories). The Internet was coded as a separate technology when its contents (e.g., information on specific websites) were used for learning, but not when it was used as a medium of communication (as in e-mails) or as a delivery system (e.g., online course management software). Similarly, servers and generic software were not coded unless they were directly used to support learning or collaboration. When researchers differ in their usage of terms, we followed the more conventional description used by majority of the researchers. For example, discussion boards were sometimes described as conferencing technology [29-30], but are considered more widely as a discussion board and were thus coded as such.

A paper could be assigned multiple technology codes when the study compared the effect of different technologies (e.g., shared wireless laptop vs. shared workspace) [31] or when several different technologies were used together (e.g., mobile device with representational tools such as concept maps or simultaneous use of chat and blogging) [32-33]. In a few cases, individual technologies were collapsed into one when they constituted a package (e.g., a tutorial containing visualization and simulations of the learning materials) [34] or an integrated environment (e.g., WISE; Web-based Inquiry Science Environment) [35] that were examined as a whole without a specific research focus.

#### 2.3.2. Collaboration. Collaboration refers to the types of interaction that occurred among learners. There were four types of collaboration: (1) Face-to-face, (2) Distributed: Synchronous, (3) Distributed:
2.3.4. Educational levels. Since most of the research papers studied students, the following three educational levels were used: (1) K-12 for primary and secondary education settings, (2) Higher education (i.e., undergraduate and graduates), and (3) Other (e.g., professionals). Multiple coding was allowed when more than one level was studied.

2.3.5. Pedagogical approaches. Pedagogical approaches refer to the instructional strategies used by teachers. They reflect teachers’ beliefs about how learning occurs and how to best promote learning. Pedagogical approaches were coded into the following categories: (1) Traditional instructions (e.g., lectures), (2) Distance learning (e.g., learning in online courses), (3) Case-based instruction, (4) Problem solving, (5) Problem- or Project-based learning, (6) Design-based learning, (7) Discovery learning, (8) Hands-on/active learning, (9) Inquiry, (10), Game, (11) Discussion, (12) Script/roles, (13) Argumentation, (14) Scaffolding, (15) Miscellaneous collaboration, (16) Other approaches. Space does not permit us to describe these pedagogical approaches in detail, but they often emphasize different instructional activities. For example, in case-based instruction, learning takes place around analyzing case examples. Examples are selected to highlight prototypical features and/or contrast important dimensions [38]. In problem-based learning, students learn through solving problems collaboratively and reflecting on their experiences. 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 of human physiology in the context of diagnosing disease) [31, 39-40]; in the latter, problems are used as a context of applying and practicing what they have learned previously (e.g., exercise in mathematical word problems) [41]. In design-based learning, students’ activities are structured around designing artifacts (e.g., car) [42-43]. In discovery learning, students explore and experiment with the materials in an unguided manner and are encouraged to discover important principles of domain by themselves without being taught. In hands on/active learning, students engage in active hands-on activities such as manipulating a tool and making artifacts [4]. In inquiry learning, the emphasis is on learning the process of inquiry, so that students can think and reason as scientists themselves [35, 44].

In discussion pedagogy, students are asked to engage in discussions of the learning materials. While students’ interaction is rather unstructured in this case, in script/roles, students are asked to follow certain scripts and/or roles that specify which activities need to occur, in what order, and by whom [10, 37, 45-46]. In argumentation, students are asked to argue their beliefs against another student or
groups and construct a sophisticated understanding in the process. In scaffolding, another learner assumes the role of helping students’ learning by monitoring their progress and providing feedback [47-48]. Miscellaneous collaboration pedagogy includes other collaborative pedagogy such as jigsaw method where students each carry out different portions of a task and later combine their individual work [33]. These five approaches are called collaborative pedagogy in this study. Although other pedagogical approaches can incorporate and emphasize collaboration, their focus on collaboration is mostly secondary. On the other hand, these five collaborative approaches specifically focus on collaboration with emphases on different ways of collaboration.

Pedagogical approaches were coded only when some kinds of instructions occurred. Studies that did not include instruction (e.g., technology use at professional conferences) were thus excluded from this coding. Typically, bits and pieces of different pedagogical approaches are incorporated together in a given CSCL application or environment. For example, distance learning courses were often implemented with regular online conferences or topic discussions [29-30, 36]. Problem-based learning was also implemented with script/role assignments [41]. Instead of coding one overarching pedagogical approach, we thus coded salient instructional strategies used in the study.

3. Results

3.1. Technology

The frequencies of technology use are shown in Figure 1. Of the coded technologies, the most commonly used technologies for CSCL were discussion boards (33%) and chat (30%). The next most frequently used technologies were mobile technologies (12%), representational tools (15%), and intelligent systems (12%). Several technologies did not appear in our sample (e.g., wiki, virtual reality), but this may be due to the small sample size. The result that the other technology had the highest frequency was unexpected, but reveals the diversity of technology applications in CSCL. A closer examination of the other category showed that about half of them were stand-alone, often commercial, applications. For example, the SPSS, statistical software, was used in collaborative statistical problem solving in one study [49]. A word processor was used to compose messages before writing a chat message in another study [50]. Also included in the other technology were peer assessment systems [47, 51-52], shared workspaces [42, 53], and learning environment such as the WISE (Web Integrated Science Environment) that were specifically designed for CSCL [35].

![Figure 1. Technology](image)

A single study often implemented multiple technologies. The mean number of technologies implemented in a study was 1.82. Note that the actual number of individual technologies in CSCL research can be larger because we occasionally collapsed different technologies into one. About half of the papers (52%) studied a single technology such as simulation or chat, and about one third (30%) of the papers studied two technologies. The rest of the studies used more than two technologies.

3.2. Collaboration

Frequencies for the collaboration codes are presented in Figure 2. The results showed that learners in CSCL environments engaged in distributed asynchronous collaboration most frequently (48% of the studies), followed by face-to-face (39%) and distributed synchronous collaboration (36%). The other interaction type included indirect collaboration through peer assessment systems [51], collaborative filtering [54], or resource sharing [31]. Learners also engaged in more than one type of collaboration in a single study [32, 55-58], but the majority of the studies (70%) used one type of collaboration.

Face-to-face collaboration was supported by a diverse range of technologies such as tutorials, statistical software applications, and handheld computers. Students typically shared the technology and interacted around it, but in some cases had their
own devices or applications. For example, in one study students engaged in face-to-face collaboration each with their own handheld device [41]. 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. In case of synchronous collaboration, it was mostly supported via chat (83%) and then by video-conferencing (17%). Asynchronous collaboration was supported by diverse technologies. Although discussion boards (62%) were used most frequently, other technologies such as e-mails (12%), peer assessment systems (12%), blog or virtual post-its (6% each) were also used as tools of asynchronous collaborations.

Figure 2. Collaboration

3.3. Learning domains

CSCL technologies were used in a range of domains, as shown in Figure 3. Of the coded domains, science/math and professional (24% each) were most frequently used as learning contexts. Literacy/history (15%) and social sciences (12%) were next most frequently used learning domains. The emphasis on science/math may reflect the funding pattern for CSCL research, most notably in the United States, coming from the National Science Foundation. Many applications of CSCL research were carried out in other domains (27%), which included cross-discipline domains and hard-to-categorize or unclear domains. Although most CSCL research dealt with learning academic domains, there were a few application of CSCL in non-academic contexts. One study, for example, used an orientation task for a university rally that was designed to help event participants (e.g., parents, visitors to the university) to get to know the university. In this study, participants engaged in problem solving activities as they roam different parts of the university with mobile devices.

Although the sample size was too small to definitively determine whether specific technology or collaboration types were associated with specific domains, we selected the two most widely used technologies (i.e., discussion board and chat) and examined whether they are used differently across learning domains. The two tools were used most frequently in social sciences (75%) and literature/history (60%), then in professional (50%) and science/math (37%). This differential technology use across domains seems to be related to the kinds of collaboration supported by technology in each domain. Technology supported face-to-face interaction mostly frequently in science/math (62%), followed by social science (50%), literature/history (40%), and professional domains (37%). More analyses needs to be done, but it seems that technologies are used to support face-to-face collaboration around computers in science/math more so than in other domains. This may be due to the complexities of learning complex scientific phenomena and concepts collaboratively over distance.

Figure 3. Learning domains

3.4. Educational levels

Educational levels used in CSCL research is presented in Figure 4. The majority of the learners was in higher education (58%), followed by K-12 (36%) and other (6%). Learners in K-12 and higher education seemed to be differentially supported by technology. In K-12, technology supported face-to-face collaboration (50%) more frequently than distributed synchronous (17%) or asynchronous collaboration (25%). On the other hand, in higher education, technology supported distributed collaboration (42% for synchronous and 58% for asynchronous) more frequently than face-to-face collaboration. The use of face-to-face CSCL in K-12 educational is not surprising as learners are in the
same building on similar time schedules. In contrast, in higher education settings, learners may be in different locations and have a variety of scheduling constraints.

![Figure 4. Educational levels](image)

### 3.5. Pedagogical approaches

The pedagogical approaches in CSCL research are summarized in Figure 5. Perhaps not surprisingly, collaborative pedagogy was implemented most frequently (45%), followed by distance education (21%), problem/project-based learning (15%), and problem solving (12%). Except in one study, distance education was always complemented by one of the collaborative pedagogies [29], suggesting that CSCL is often used to remedy some of the shortcomings of distance education where students typically have little chance to interact with each other.

![Figure 5. Pedagogical approaches](image)

### 4. Discussion

This study investigated technology use in CSCL. A content meta-analysis of empirical CSCL research showed that CSCL environments typically embed more than one technology, probably in reflection of the realization that adoption of a single technology is often insufficient to the desired outcomes. Communication technologies such as discussion boards and chats were most commonly used, but a diverse set of non-communication technologies is also used in CSCL. Technologies supported distributed collaboration more frequently than face-to-face collaboration. Distributed synchronous collaboration was supported mainly by communication tools such as chat or video-conferencing, whereas face-to-face and asynchronous collaboration were supported by more diverse tools such as discussion boards, simulations, intelligent systems, or blogs. CSCL supported learning across a range of disciplines, but is more likely to be studied in higher education than in primary or secondary educational contexts. A number of interesting interactions between technology, collaboration, and learning contexts also emerged from the analyses.

The analyses of this study expanded and elaborated our understanding about the kinds and nature of supports technologies provide for collaborative learning in CSCL. Building upon earlier conceptualizations [18, 23], we propose five ways technology supports collaborative learning. First, technologies can support collaborative learning by providing a focal point of interaction around which learners discuss, argue, and explain [18]. Technologies such as simulations, the Internet, applications that scaffold learners with explanation and meta-cognitive prompts are all frequently used collaboratively [31, 59-60].

Second, technologies can support collaborative learning by facilitating communication and interaction. Technologies such as chat and conferencing tools make distributed collaboration possible as partners in remote locations can interact synchronously with the help from these tools [56, 61-64]. Technologies such as discussion boards or e-mails also allow learners to interact whenever and wherever they want [36, 56]. These types of technologies are necessary in certain contexts such as in distance learning, but are extensively used in other contexts as well.

Third, technologies can be used to support collaborative learning by imposing structures and constraints on the interaction process [23]. Researchers have reported that learners do not always engage in activities associated with the outcomes of collaborative learning [13-14, 45, 65]. Technologies can be used to guide learners toward task-specific interactions. For example, mandatory sentence openers or prescribed message categories in
communication interface can help learners to engage in more task-specific interactions [66-67]. CSCL has also implemented scripts and/or roles so that critical collaborative learning activities can be facilitated [68].

Fourth, technologies can be used to support collaborative learning by providing tools and resources to manage and regulate interaction processes. Representational tools such as whiteboards and graphic tools complement communication processes by providing deictic cues and also make the interactive process explicit [33, 56, 69]. They become the basis of negotiating shared meaning and common grounds during interaction. The resulting artifacts, be they argumentation maps or diagrams, 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 [31].

Fifth, technologies can be used to support collaborative learning by creating new forms of interaction. Traditionally, interaction meant direct person-to-person interaction. In the past, such communication happened via face-to-face interactions or through mail exchanges. Communication technologies make it possible to interact through e-mails or chat, but they still mediate 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 [31, 51, 54], or peer feedback system [51-52]. Interaction with non-human agents is also used as a way to monitor and support human learning [64].

Because the sample size of the current study was quite small, the conclusions are tentative until additional analyses can be conducted. However, our study highlighted important characteristics of technological support for collaborative learning in CSCL. There are many ways that technologies are used in learning contexts, but not all of them necessarily support learning. Calculators may help student to calculate faster, but they do not necessarily help students to learn calculation faster or better. The argument for learning technology is not about making students do things faster, but rather about helping them learn better. In this sense, CSCL technologies need to do more than merely making interaction easier or faster. They need to enhance and facilitate the core processes of collaborative learning [23]. In order to evaluate how CSCL as a field accomplishes this goal, we need to go beyond understanding technical features of CSCL technologies. We need to understand nature of their support for collaborative learning and the contexts of their implementations.

Understanding the recurring perhaps more prototypical combinations of technology supports for collaborative learning across a range of learning domains and educational contexts can also help designers and instructors decide how they can take advantage of new technological tools for enhancing collaborative learning. Research syntheses, as in the present study, are important in helping us understand critical aspects of technological supports for collaborative learning in their full complexity. Understanding how CSCL applications have been used will enable us to both learn from the past, and more importantly, design for the future.

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5. References


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* indicates papers included in the meta-analysis.