Synergies Among the Pillars

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Designing for Computer-Supported Collaborative Learning

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Abstract

Computer-Supported Collaborative Learning (CSCL) research has become pervasive in STEM (science, technology, engineering, and mathematics) education over the last several decades. Guided by sociocultural and social constructivist theories of learning, CSCL focuses on shared meaning making and is influenced by the three pillars of CSCL: enabling technologies, pedagogical designs, and modes of collaboration. This chapter identifies different approaches to CSCL that involve different combinations of these pillars. Based on an extensive literature review, we identify four distinct clusters that represent these different combinations. Focusing on two of these clusters, this chapter (1) identifies robust themes in this field and (2) discusses the positive outcomes associated with these aspects of CSCL. Outcomes include learning gains, process improvements, and affective outcomes. Across clusters, results demonstrate that scaffolding and feedback in different combinations are important for positive outcomes. However, feedback

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that is poorly timed or excessive sometimes impedes learning and affective outcomes. Moreover, different combinations are used with learners at different ages and learning goals. Designing CSCL for different learning environments requires considering the complex system of learning environments that emerge from the interaction among the learning contexts, learner characteristics, and learning activities.

Keywords

CSCL · Pedagogy · Collaborative learning · Technology

Introduction

Many contemporary theorists characterize learning as that which is fundamentally social rather than individual (Danish & Gresalfi, 2018). Advances in computer technologies have enabled diverse modes of collaboration and set the stage for Computer-Supported Collaborative Learning (CSCL). CSCL refers to collaborative learning that is mediated in some way by computer technology (Stahl, Koschmann, & Suthers, 2014). It rests on three major pillars: the technologies that support and enable CSCL, the pedagogical designs that apply CSCL to learning, and the modes in which learners collaborate. In describing the goal of research in CSCL, Miyake (2007) argued that to understand how CSCL research was fulfilling its goals, it is essential that research on learning "takes collaboration seriously, and implements and evaluates technological support to materialize effective learning designs" (p. 248). This addresses these three key foundations of CSCL. Similarly, Roschelle, Bakia, Toyama, and Patton (2011) have argued that we need to understand the compound resources at play in complex learning environments. By looking at different combinations of CSCL design elements, we move closer to being able to understand how to design for CSCL in different contexts. In this chapter, we will consider how different combinations of these pillars affect the outcomes of CSCL research with a focus on science, technology, engineering, and mathematics (STEM) education, where much CSCL research has been conducted (Jeong & Hmelo-Silver, 2012).

CSCL: An Overview

CSCL is consistent with a connected and ubiquitous vision of learning that takes advantage of unique affordances of technology (Miyake, 2007). Technology can lead to fundamental changes in teaching and learning practices, particularly in providing opportunities for students as engaged participants, working collaboratively in meaningful tasks (Roschelle, 2013). In particular, technology can enable new possibilities for interaction and feedback, communication, scaffolding, as well as providing meaningful tasks (e.g., simulations) and audiences.

The pillars of CSCL, what Kirschner and Erkens (2013) called the tryptic, are the technology, the pedagogy, and what they call the social aspects of learning, which includes the mode of collaboration. CSCL environments may be synchronous, that is, with learners collaborating at the same time, or asynchronous, with learners collaborating at different times. Synchronous collaboration can be at a distance, as in web conferences, or it can be face-to-face. An example of synchronous face-to-face CSCL is secondary school students discussing simulations in their classroom together (e.g., Echeverría et al., 2012; Sinha, Rogat, Adams-Wiggins, & Hmelo-Silver, 2015), whereas an asynchronous CSCL design can involve learners distributed across time and space (e.g., Yukawa, 2006). This review takes a broad view of technology, with the perspective that the computer-supported component of CSCL is used as an inextricable part of collaborative learning in a variety of contexts. Thus, we include technologies that serve a range of functions in CSCL (Jeong & Hmelo-Silver, 2016) and go beyond serving as communication channels.

Within CSCL, the focus is on learning through technology-mediated collaboration as a coordinated effort to build shared knowledge (Roschelle, 2013; Suthers, 2006). Although the CSCL community has largely focused on social constructivist and sociocultural approaches to CSCL (Stahl et al., 2014), a broad range of theoretical perspectives can apply (Hmelo-Silver & Jeong, 2021; Jeong, Hmelo-Silver, & Yu, 2014). An inclusive view of CSCL also needs to consider other theoretical frameworks such as information processing (Jeong et al., 2014). Still, in an earlier review of CSCL, a general constructivist orientation or sociocultural framework accounted for the majority of the CSCL articles (Jeong et al., 2014). Thus, we ground our discussion of the theoretical basis for CSCL in these constructivist and sociocultural frameworks, as they have been the dominant paradigm. In particular, we focus on what affordances are needed for technology to support CSCL.

Within this paradigm, *constructivism* refers to a broad range of theoretical approaches that emphasize active learner processing and knowledge construction either in individual or collaborative settings (Chi & Wylie, 2014). Social constructivism tends to emphasize how knowledge is socially constructed and leads to individual learning. *Sociocultural theory* refers to a family of theories such as Vygotskian approaches, distributed and/or situated cognition, or activity theory that emphasizes the fundamental role of tools, activities, social norms, and systems (Danish & Gresalfi, 2018). These theories consider the role of tools as mediators of learning as well as a means of providing support for task completion. An important but subtle distinction between social constructivism and sociocultural theory is that the former views the social context as an influence on individual learning, whereas the latter considers participation in the sociocultural context part of learning.

These theoretical perspectives help in considering how to design for CSCL, in particular, thinking about the functions that might be addressed in different CSCL designs. Jeong and Hmelo-Silver (2016) proposed seven affordances of CSCL for learning. Affordances refer to the ways that technology can provide opportunities for particular kinds of functions that mediate learning. CSCL technologies provide learners opportunities to (1) engage in a joint task, (2) communicate, (3) share resources, (4) engage in productive collaborative learning processes, (5) engage in co-construction, (6) monitor and regulate collaborative learning, and (7) find and build groups and communities. Different combinations of these functions can be used in CSCL designs to support a range of instructional designs and pedagogical approaches.

Effects of CSCL on Learning

Recent meta-analyses suggest that CSCL has significant effects on student learning (Chen, Wang, Kirschner, & Tsai, 2018; Jeong, Hmelo-Silver, & Jo, 2019; Vogel, Wecker, Kollar, & Fischer, 2017). Chen et al. (2018) examined the role of collaboration, computer use, and overall CSCL environments on learning. They found overall moderate effects of CSCL on learning outcomes and social interaction with large effects on group tasks. Vogel et al. (2017) restricted their meta-analysis to scaffolding with CSCL scripts. Their results demonstrated small effects on knowledge gains and a moderate effect on collaboration skills. However, they found that scripts were particularly effective for learning domain knowledge when they prompted learners to engage in activities that built on the contribution of other group members or when they provided additional content-specific support. Jeong et al. (2019) restricted their meta-analysis of CSCL to research in STEM education domains but found a similar overall moderate effect size, similar to Chen et al. (2018). They did find, however, that effect sizes were moderated by types of technology and pedagogy, education levels of learners, and modes of collaboration. There were also interactions among these moderator variables. For example, representational tools (e.g., simulations, modeling tools) were more effective in face-to-face than in asynchronous settings as was inquiry learning. The use of scripts and discussion boards were more effective in asynchronous settings.

The results across these meta-analyses suggest that CSCL is effective overall. However, these studies also noted different factors that moderated the effectiveness of these approaches. Jeong, Hmelo-Silver, & Jo (2019) drew from a larger corpus of CSCL research that included research with a larger variety of research methods that were coded for types of technologies, pedagogies, and collaboration mode (McKeown et al., 2017). This meta-synthesis found that there was not just one CSCL but rather four unique interpretable clusters of CSCL designs (presented in order of largest clusters):

- **Face-to-Face Inquiry with Dynamic Feedback** – face-to-face collaboration, inquiry and exploration pedagogies, and dynamic or other tools.
- **Asynchronous Teacher-Structured Discussion** – asynchronous collaboration, discussion or teacher-structured pedagogies, and asynchronous communication technologies.
- **Online Generative Inquiry** – asynchronous or face-to-face collaboration, inquiry and exploration or teacher-structured pedagogies, and sharing and co-construction technology.

- **Synchronous Collaboration** – synchronous collaboration and communication technologies.

Space precludes discussing all these in detail, and thus we focus on the two inquiry-oriented clusters, the first and the third largest, to show how CSCL has been used in different learning designs. We summarize these and provide examples next.

Face-to-Face Collaborative Inquiry with Dynamic Feedback (F2FCI). This cluster emphasizes face-to-face collaboration with inquiry and exploration pedagogies using dynamic technological tools such as simulations, games, and immersive technology. In addition, a substantial number of the papers in this cluster also used sharing and co-construction tools. Within the cluster, the majority of papers were in K-12. The inquiry pedagogy was generally supported by rich task contexts such as simulations and games as authentic contexts for inquiry.

Outcomes. Learning under this type of CSCL led to significant learning gains, promoted student engagement, and supported positive process outcomes such as critical thinking and reasoning skills. These outcomes cut across quantitative and qualitative studies, disciplinary content, and education levels. K-12 math students improved their problem-solving skills (Gallardo-Virgen & DeVillar, 2011; Roschelle, Rafanan, Estrella, Nussbaum, & Claro, 2010; Sao Pedro, Baker, & Rodrigo, 2014), conceptual understanding in mathematics and physics (Lai & White, 2012; Turcotte, 2012), and group collaboration and communication skills (Chen, Looi, Lin, Shao, & Chan, 2012). In physics, positive effects on learning gains were found in primary and secondary education (Turcotte, 2012; Echeverría et al., 2012, respectively). Primary students experienced positive learning gains and improved critical thinking skills from designing digital science games in an integrated biology and computer science curriculum (Yang & Chang, 2013). Primary students who were guided either with awareness tools or scripts learned more about photosynthesis through a drawing task than students in a control condition (Gijlers, Weinberger, van Dijk, Bollen, & van Joolingen, 2013). Students in both experimental conditions engaged in higher quality discourse than control participants.

F2FCI research also highlighted positive effects on student engagement and affective measures at multiple education levels. Primary students using handheld devices in an authentic outdoor learning task were enthusiastic and developed great interest in the assignment (Avraamidou, 2013). Secondary biology students who participated in a CSCL review game were more engaged than students in the control group who participated in traditional paper and pencil review sessions with CSCL support (Annetta, Minogue, Holmes, & Cheng, 2009). Additionally, computer science secondary and tertiary students felt empowered in their own learning (Tsai, Tsai, & Hwang, 2012).

Furthermore, lessons using dynamic technologies with inquiry and exploration pedagogies promoted meaningful interactions between elementary students, which in turn led to greater learning outcomes (Lai & White, 2012). For example, students engaged in high-quality interaction patterns, which entailed discussing the problem, task delegation, and helping each other in turn complete more assignments correctly than students with poor communication and collaboration (Chen et al., 2012).

Similarly, in the domain of ecology, primary science students engaged in an augmented reality mobile inquiry learning activity produced greater knowledge construction interactions than those in the control group (Chiang, Yang, & Hwang, 2014).

Factors that support effectiveness. Overarching themes that emerged from this cluster are that (1) pedagogies that support guided collaborative inquiry and (2) rich problem contexts that establish a joint task promote positive outcomes (Avraamidou, 2013; Chiang et al., 2014; Jaakkola & Nurmi, 2008; Kong, Yeung, & Wu, 2009; Kuo, Hwang, & Lee, 2012; Lai & White, 2012; Loke et al., 2012; Santos-Martin, Alonso-Martínez, Carrasco, & Arnaltes, 2012; Tsai et al., 2012; Yang & Chang, 2013). Authentic problem contexts could be set in games and simulations (e.g., Echeverría et al., 2012; Nelson & Ketelhut, 2008). One way that facilitators provided guided instruction was by giving assistance and feedback throughout collaborative inquiry and by providing authentic problems for problem-based learning (Avraamidou, 2013; Santos-Martin et al., 2012). A similar approach was taken with case-based instruction by developing workshops for pharmacy students to simulate real-life scenarios (Loke et al., 2012).

Instructors provided guided instruction ranging from very open-ended to more highly structured. For example, undergraduate and graduate students were given very open-ended guidelines as they engaged in mobile learning outside of the classroom (Tsai et al., 2012), whereas secondary-level students were provided more facilitation in a student-driven augmented reality game to help them learn electrostatics (Echeverría et al., 2012). Even greater structure was provided for primary grade students who were given systematic processes to follow as they engaged with highly organized inquiry learning to help them with knowledge sharing (Chiang et al., 2014). In a grade 5/6 study of Knowledge Forum, teacher and researcher questions were helpful in advancing student thinking (Turcotte, 2012).

In comparing task awareness tools with process-support scripts, Gijlers et al. (2013) found that support in the form of a script led to more interactive talk and differences in the ways that elementary school learners engaged with the task of drawing the photosynthesis process. The awareness tools, which prompted students about objects that were missing from their drawings, led students to go back to the concepts in their resource text, whereas students in the scripted condition were more likely to integrate elements from their individual drawings into a shared drawing. Guided instruction also took the form of companion worksheets with primary students (Jaakkola & Nurmi, 2008; Lai & White, 2012).

Closely tied to the theme of guided inquiry is feedback (Hmelo-Silver et al., 2007). In studies with F2FCI with dynamic feedback, participants at a variety of educational levels received immediate feedback on a task or problem from facilitators (Avraamidou, 2013; Kong et al., 2009; Santos-Martin et al., 2012), peers (Chen et al., 2012; Chiang et al., 2014; Gallardo-Virgen & DeVillar, 2011; Kuo et al., 2012; Lai & White, 2012), and/or software (Chen et al., 2012; Echeverría et al., 2012; Holmes, 2007; Loke et al., 2012; Roschelle et al., 2010). Software feedback could include direct hints or prompts or be more indirect in providing changes in the state of a simulation or game in response to learner actions. Teachers noted elementary student achievement and success with technology use required active teacher feedback (Chiang et al., 2014; Kong et al., 2009).

Factors that inhibit effectiveness. Collaborative tasks are particularly complex as Gijlers et al. (2013) also demonstrated in their control condition, and they require support. The factors that may inhibit student learning and engagement are related to feedback. An example of the importance of informative feedback emerged from two studies with primary students and teachers. When teachers lack content expertise, the technology itself needs to have that content feedback embedded or risk leaving student questions unanswered, as in an example of using software for learning about electrical circuits (Kong et al., 2009). This is also a problem when a teacher is working with several groups and cannot provide consistent active feedback for each group (Chiang et al., 2014; Kong et al., 2009), or for students who have specific questions about technology or content, and the teacher is unable to answer (Kong et al., 2009).

Although this concern with the lack of consistent, active feedback only emerged between these two studies with primary students, they are pedagogical and technological concerns applicable at all educational levels. Technologies can be used to provide content feedback in such situations, but as Turcotte (2012) noted, just because technology provides affordances for particular kinds of activity such as elaborated explanations, learners do not always take advantage of those affordances.

Summary and implications. Among these papers, there was a trend for students to be collaboratively engaged with authentic problems and their learning nurtured by guided instruction, feedback, and discussion. Together, these combinations were associated with significant learning gains, positive student engagement, meaningful interactions between students, and improved group collaboration and communication skills.

Simulation tools and augmented reality games allow students opportunities for practice, feedback, and revision as they collaboratively engage with disciplinary content and practices without the time or expense of physical tools. Learning with authentic problems was supported by opportunities for guided inquiry and immediate feedback from the tools and discussion (i.e., Echeverría et al., 2012; Holmes, 2007). Technology played a role in helping students to work in settings that are more authentic and have opportunities to directly test their ideas and solutions, with the tools providing dynamic feedback. The main difference between the higher education and K-12 school environments was the control retained by the instructor. When this design was used in higher education, students had greater autonomy than primary and secondary education students. Question remained, however, about how much information needs to be embedded in the technology and how to help teachers support their students.

Online Generative Inquiry (OGI). This cluster of articles was primarily concerned with integrated learning environments (e.g., learning management systems) or online sharing and co-construction technologies (e.g., wikis, participatory technologies). Asynchronous collaboration with inquiry and exploration pedagogies was a main focus, but collaboration and pedagogy were more varied than in some of the other clusters. By their nature, integrated environments offered instructors and students a variety of tools that could be used to collaborate asynchronously or in face-to-face environments. Most OGI papers examined learners in higher education, again suggesting some connection between learner education level and collaboration types, consistent with the Jeong et al. (2019) meta-analysis. Communication and discussion occurred through sharing/co-construction tools and integrated environments that allowed direct communication through built-in chat tools or discussion forums.

Outcomes. Research in this cluster primarily reported process gains as well as some learning gains. The positive process gains highlighted in this cluster included metacognitive skills supported by a knowledge-building environment (Pifarre & Cobos, 2010) and improved reasoning and collaboration via e-learning environments or wikis (Huang & Nakazawa, 2010). In an undergraduate statistics course, student report writing was completed individually or collectively via a wiki (Neumann & Hood, 2009). There were no differences in terms of final report quality, but students who collaborated within wikis were more engaged and had higher attendance than those who worked alone. However, this technology is not without its challenges, as some students reported dissatisfaction with using the technology, and task completion was negatively affected by low group member participation in some instances (Neumann & Hood, 2009).

Learning gains in this cluster were not uniform. On one hand, collaborative use of a multimedia-enriched concept map produced greater short- and long-term retention scores than a control group that received regular instruction and worked on assignments individually (Marée, van Bruggen, & Jochems, 2013). However, another study found no differences between the final grades of a group that collaborated through wikis and a group that worked independently with a word processor, despite positive engagement (Neumann & Hood, 2009). Mixed learning gains were reported in Krause, Stark, and Mandl (2009) that examined learning gains with students working individually versus pairs, and with some students receiving automatic adaptive feedback in an asynchronous statistics class. In this example, students who received feedback performed better than those who did not. Feedback tended to reduce the gap in outcomes between students with low and high prior knowledge.

Factors that support effectiveness. A wiki co-construction environment demonstrated that students reported more interaction with peers than with their instructor and that the instructor moved to more of a moderator role, allowing students to initiate interactions (Huang & Nakazawa, 2010). Students also noted the importance of receiving public feedback about revisions within the wiki where these could be discussed by group members, instead of privately or over other media, allowing the feedback to function as collaborative scaffolding and an anchor for their discussions. In using representational tools, Marée et al. (2013) found that undergraduate science students could learn more with less teacher guidance using multimedia-enriched concept maps with embedded instructions for collaboration.

This OGI research also offered some promising implications about specific technologies and pedagogical practices. For example, in asynchronous discussion threads (i.e., a specific technology), particularly when students act as facilitators (i.e., a pedagogical practice), they need to understand different types of thread patterns and how questioning, summarizing, pointing, and resolving may affect discussion thread development and closure (Chan, Hew, & Cheung, 2009). Pedagogically, in ICT courses, it is important to integrate the technology being discussed so participants better understand its purpose and also how to use it themselves (Goktas & Demirel, 2012). Krause et al. (2009) supported the notion that feedback, whether from instructors or peers, may promote more reflection, especially when it offers explanations that encourage deeper understanding. Therefore, regardless of the source, feedback should be thoughtful and thorough and encourage students to think beyond remembering information. Pifarre and Cobos (2010) demonstrated the importance of scaffolds in improving peer questioning and co-regulation.

Many of these papers investigated how students used and perceived specific technology. These suggest that the use of collaborative group activities, instructors' timely feedback, and support materials embedded within an integrated system all related to student satisfaction with a variety of STEM-related vocational e-learning courses (Inayat, ul Amin, Inayat, & Salim, 2013). Similar to the F2FCI cluster, when guided instruction and immediate feedback are integrated within these pedagogies and technologies, it can lead to improved student learning (Krause et al., 2009; Marée et al., 2013) and task completion (Hämäläinen & Arvaja, 2009).

Although scripts might be effective for task completion, they do not necessarily avoid variability in collaboration processes among groups. In a study of university students engaging in case-based learning, Hämäläinen and Arvaja (2009) still found differences in frequencies and meaningfulness of collaborative activity with five out of the seven groups showing unequal participation or one group member being dominant. Thus, the structure applied by a script may not be sufficient to promote uniformly productive collaboration.

Factors that inhibit effectiveness. Again, feedback was mentioned in relation to factors that inhibit effectiveness. Consistent with findings in other clusters, a lack of feedback can negatively affect students' learning outcomes (Krause et al., 2009). Meanwhile, too much feedback, or using facilitation techniques that resolve conflicts or summarize key points, can lead to discussions closing prematurely (Chan et al., 2009). Without enough guidance regarding the importance of positive collaboration, students may have high task activity, but not necessarily high-quality collaboration (Hämäläinen & Arvaja, 2009).

Summary and Implications. Timely guidance from teachers and peers plays an important role in increasing student outcomes as well as favorable perceptions of the environment. The results for this cluster also highlighted the importance of keeping the guidance at an optimal level; there is a delicate balance between too much and not enough feedback or guidance.

In contrast to F2FCI, which also supported inquiry and exploration, communication modalities in this cluster make students' thinking visible in ways that a face-to-face classroom may not allow. Teachers can thus follow persistent threads of synchronous and asynchronous discussion along with the artifacts being created. This gives teachers opportunities for ongoing formative assessment. More speculatively, it may also provide grist for student reflection on these ongoing interactions in ways that face-to-face discussions that are more ephemeral may not. This may be particularly important in higher education contexts with their larger class sizes that might otherwise offer fewer opportunities for discussion and feedback.

Open Questions and Directions for Future Research

It is clear that the three pillars of CSCL – collaboration, technology, and pedagogy – are used in different combinations to design effective learning environments. However, we need to better understand how to design for the balance between developing appropriate structures and supporting student agency in ambitious learning practices promoted by CSCL (Glazewski & Hmelo-Silver, 2019). This is particularly important in being able to support diverse learners (Uttamchandani, Bhimdiwala, & Hmelo-Silver, 2020). We review this in the context of the major issues this chapter has identified.

First, feedback and support are themes that run through all the clusters, whether the feedback is from the teacher or peers or from tools. Much research has focused on teachers and software but less has addressed ways to support high-quality peer feedback (De Wever, Van Keer, Schellens, & Valcke, 2010). Certainly, research on scripts and roles may be one way to provide such support for good quality peer feedback, but these kinds of interventions tend to focus on process support rather than on feedback. CSCL environments should provide feedback for students and information that allows teachers to support multiple groups (Chiang et al., 2014; Kong et al., 2009). Questions about feedback consider both the timing and quality. Poorly timed feedback that does not address appropriate content, skills, or practices may impede learning. As the reference to synergy in the title suggests, it is important to think about feedback and support as part of the CSCL system of technologies, pedagogies, and collaboration modes. It is important to consider which aspects of feedback and support should be fixed and which should be adaptive.

Second, certain technologies lend themselves better to particular communication channels and/or pedagogical goals. Dynamic representational tools are generally used in face-to-face environments as the F2FCI cluster demonstrates (e.g., Lai & White, 2012; Nelson & Ketelhut, 2008). We conjecture that the rapid cycles of activity and engagement with such tools lend themselves to the immediacy of being in the same place at the same time. Additionally, the tools allow for deictic referencing as learners can easily point to phenomena on-screen and observe the gestures of others.

Our meta-analysis (Jeong et al., 2019) showed that effect sizes were larger when dynamic representational tools were used in face-to-face settings. Similarly, the use of sharing and co-construction tools dominated the OGI cluster. These tools may be more critical for online environments because learners' interaction channels are limited and thus need to be mediated by communication tools. When communicating and collaborating with these tools, learners need to be more explicit about their actions and contributions, which can provide a chance for reflections. Knowledge co-construction can be fostered when learners can articulate their ideas more clearly and make their contribution explicit.

Third, different learning environments are used for different learners. We found that CSCL involving younger learners tends to involve face-to-face collaboration rather than online collaborations. Online collaboration requires dealing with a broader range of communication modalities and as such may be used for more mature learners (Jeong & Hmelo-Silver, 2012). We do not know if it is because of better self-regulated learning skills for older learners or more convenience or available technology. In general, the trend seems to be for more structure and face-to-face collaboration for younger learners. Moreover, face-to-face CSCL is more commonly used for younger learners, perhaps due to the need for social presence in this population as they tend to be in the same physical space. In addition, technology tools can add to the cognitive demands on learners and pose increasing challenges for regulation that may be difficult for younger learners. However, these challenges are not unique to younger learners. There is a large body of literature that suggests that creating social presence and self-regulated learning is challenging even for more mature learners in online environments (e.g., Garrison, 2007; Järvelä & Hadwin, 2013).

Fourth, CSCL tasks are important, whether providing rich contexts or opportunities for joint construction of artifacts, particularly in those clusters that focus on inquiry and explanation. For example, in F2FCI, the establishment of rich task contexts was supported by the use of technology (e.g., simulations, games, and devices) and collaborative inquiry pedagogy (e.g., Chiang et al., 2014; Lai & White, 2012; Santos-Martin et al., 2012).

These authentic joint tasks promoted positive outcomes. The technology used here allowed learners to engage with tasks that were fundamentally different from what they could do without the CSCL technology. For example, the dynamic feedback from a game or simulation is immediate and is a consequence of particular learner actions. Paper cases that might be used in problem-based learning, for example, only provide predefined resources. In contrast, the OGI cluster uses the affordances of tools that allow construction of shared artifacts such as wikis (Huang & Nakazawa, 2010; Neumann & Hood, 2009), creating a website (Barchard & Pace, 2010), or collaborative concept mapping (Marée et al., 2013).

The last question that research on synthesis of CSCL needs to ask is what does it mean for CSCL to be effective? From different theoretical perspectives and research designs, this can mean many things, making the synthesis process challenging. It may mean CSCL is a black box that can produce content gains measured as pre- to posttest achievement (e.g., Echeverría et al., 2012; Kong et al., 2009; Pifarre & Cobos, 2010). However, it can also mean collective effectiveness such as in the research on knowledge building that focuses on collaborative improvement of community knowledge (e.g., van Aalst, 2009; van Aalst & Chan, 2007). Other authors examine the quality of discourse and patterns of collaboration processes broadly defined (e.g., Sinha et al., 2015; Van Amelsvoort, Andriessen, & Kanselaar, 2007). Still others focus on affective outcomes and learner satisfaction (e.g., Loke et al., 2012; So & Brush, 2008). Much of the research uses multiple measures (e.g., Gijlers et al., 2013; Shaw, 2013). In this chapter, we have treated what it means for CSCL to be effective broadly, but we also need to make sure that we make sense of the broad range of outcomes studied in CSCL in a coherent manner.

Together, these themes suggest overarching questions about needing to connect design features and contextual factors. Examining relationships among processes, outcomes, learner characteristics, instructional goals, and design features is critical for understanding more about "what works for whom and under what circumstances" and enabling designers to tailor CSCL designs to the intended settings.

Implications for ODDE

CSCL as a complex system. At the start, we noted the importance of considering the compound resources used in CSCL (Roschelle et al., 2011). There is no one-size-fits-all solution, and how CSCL is used in different ODDE environments needs to be tailored to the particular level of the learners and the learning goals. Designers will need to consider how the collaboration modes, technology, and pedagogical choices fit together in ways that are more than the sum of their parts. CSCL is an essential part of the complex system that emerges in enacting learning environments.

Considerations for practice. Helping stakeholders become aware of the usefulness of CSCL is a first step in implementing evidence-based practices. This includes reporting on CSCL in practitioner venues and publications. In addition, professional development is important for instructors in order to effectively implement CSCL. Facilitating CSCL requires mastering the technology, tailoring it to tasks, and providing adequate scaffolds that can be differentiated for student skills and prior knowledge.

Conclusions

It is clear that there are different technology-pedagogy-collaboration modes for different learners. We need models that help guide researchers and practitioners in how these CSCL pillars may be synergistically combined, providing the compound resources in appropriate combinations. One way to accomplish this might be to think about the function needed for a set of learning goals and considering how they might be distributed among these pillars. Jeong and Hmelo-Silver (2016), for example, have proposed that technologies serve seven distinct functions in CSCL such as establishing a joint task, providing communication channels, sharing resources, engaging in productive collaborative processes, supporting co-construction, monitoring and regulation, and forming groups and communities. These functions or affordances highlight different ways technology supports are contingent upon collaboration and pedagogy. Further work is needed to better understand how these functions might be used as part of a theory of design for CSCL and the implications for ODDE. The current chapter begins to address these important questions about CSCL and the complexity of these learning environments.

Cross-References

► Asynchronous Tools for Interaction and Collaboration
► Designing Online Learning Communities
► Designing Online Learning Environments to Support Problem-Based Learning
► Serious Games and Game-Based Learning
► Synchronous Tools for Interaction and Collaboration

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