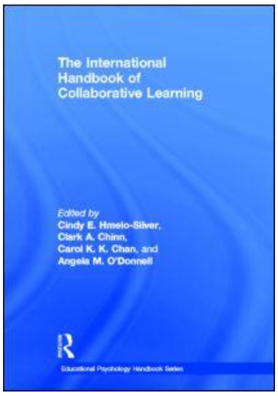


# The International Handbook of Collaborative Learning

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## Mobile Computer-Supported Collaborative Learning

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# MOBILE COMPUTER-SUPPORTED COLLABORATIVE LEARNING

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## INTRODUCTION

Computer-supported collaborative learning (CSCL) researchers have explored the types of interaction that are necessary in a collaborative team in order to produce positive learning outcomes. These include such interactions as data and idea exchanges, explanations, argumentations, conflict resolution, knowledge construction, and artifact coconstruction. The researchers have also designed learning environments and scripts which scaffold these interactions. Collaborative activities are now integrated into curricular activity systems, learning activity workflows, or pedagogical scenarios that include individual, small-group, and class-wide activities occurring in a variety of settings (e.g., classroom, home, workplace, field trips, off-campus community) and modes (e.g., face-to-face or remote; synchronous or asynchronous).

From the perspective of mobile learning (m-learning), the premise is that learners are mobile, mobile technologies are ubiquitous and ready-at-hand, and learners can learn and collaborate in context. The unique technology characteristic of "mobility" offers opportunities for learners to share and construct knowledge readily in different settings and modes. Historically, mobile technologies were introduced into education in the last decade of the 20th century, and mobile technology educational applications have taken shape at the beginning of 21st century throughout the world. Mobile-computer supported learning (mCSCL) was "discovered" among these applications at an early stage, focusing on notions of collaboration enabled by mobile devices (e.g., Colella, 2000; Soloway et al., 2001; Zurita & Nussbaum, 2004).

Researchers have also designed and tested various forms of mCSCL to support collaboration in and out of classrooms and in online learning communities. In classrooms, tools such as classroom response systems, participatory simulations, and collaborative scaffolding have been designed and adopted in mCSCL activities for enhancing interactivity, augmenting collaborative spaces, and enhancing negotiation about meaning (e.g., Davis, 2003; Klopfer, Squire, & Jenkins, 2008; Nussbaum et al., 2009). Outside the classroom, various tools on the mobile devices have been used for groups' situated, experiential, and inquiry learning in field trips or outdoor mCSCL activities (e.g., Chen, Kao, & Sheu, 2003; Rogers & Price, 2009; Wong, Chen, Looi, & Zhang, 2010). Mobile device tools have also been employed to bridge indoor and outdoor mCSCL activities, and cross the boundary between formal and informal learning (e.g., Looi, Seow, et al., 2010; Vavoula, Sharples, Rudman, Meek, & Lonsdale, 2009).

This chapter provides a summary of research and development in the emerging field of CSCL using mobile technologies, known in the literature as mCSCL (mobile CSCL). In exploring the synergies between CSCL approaches and m-learning approaches, we will review m-learning definitions and the nascent work in theorizing them. We will discuss the characteristics and affordances of mobile technologies, mCSCL pedagogical practices, and methodological issues.

## EVOLUTION OF DEFINITIONS OF M-LEARNING

In parallel with the increase in mobile educational applications is the growth of different understandings of m-learning. According to Quinn (2001, p. 21), "m-learning is e-learning through mobile computational devices"; likewise, Hoppe, Joiner, Milrad, and Sharples (2003) defined it as "e-learning using mobile devices and wireless transmission" (p. 255). Both of these definitions convey the message that m-learning is an extension of "e-learning." O'Malley et al. (2003) defined m-learning as "any sort of learning that happens when the learner is not at a fixed, predetermined location, or learning that happens when the learner takes advantage of the learning opportunities offered by mobile technologies" (p. 9). This definition, taking into consideration the "mobility" offered by mobile technologies, has a broader view than the previous ones.

Barbosa, Geyer, and Barbosa (2005) contended that m-learning is about increasing learners' capabilities to move their own learning environments physically as they move. With m-learning, the learning environment is no longer fixed to one particular location (e.g., physical classroom) or digital context (e.g., e-learning portal) but moves to wherever the learner is, hence enabling the surroundings to transform into the learning environment. This definition and characterization recognizes the importance of learning environments that transcend physical settings, emphasizing the "mobility" of m-learning in context. From these definitions, it can be noted that m-learning is evolving from a focus on intersecting mobile computing with e-learning to a focus on the "mobility" of learning in context, reflecting the shift of m-learning educational research from a technological focus to foregrounding a social, situated, and "just-in-time and -place" learning. Nevertheless, these definitional concepts barely touch on how to theorize m-learning in education.

## EXPLORING WAYS TO THEORIZE M-LEARNING

Recognizing the undertheorization of m-learning, Sharples, Taylor, and Vavoula (2007) paved the way in developing a theory of m-learning that reconceptualized learning by encompassing both learning supported by the mobile technology and learning characterized by the mobility of people and knowledge. They argued that, in order to create a theory of m-learning, it should be distinguished from other forms of learning by showing: (a) that learners learn across space as they take ideas and learning resources obtained in one location and apply or develop them in another, learners learn across time by revisiting knowledge acquired earlier in a different context, which provides a framework for lifelong learning, learners move from topic by topic by managing a range of personal learning projects rather than sticking to a single curriculum, and learners move in and out of engagement with technology; (b) how impromptu sites of learning are created out of offices, classrooms, and lecture halls; (c) a social-constructivist approach that views learning as an active process of building knowledge and skills through practice in a supportive community; and (d) the ubiquitous use of personal and shared technologies. Based on these criteria, the authors defined m-learning as "the processes of coming to know through conversations across multiple contexts amongst people and personal interactive technologies" (p. 225).

Thus m-learning is reconceptualized as a process of coming to know through conversation/communication across continually reconstructed contexts. The authors used activity theory (Engeström, 1987) as a framework, this typically being used to understand human activity in context (Cole & Engestrom, 2007). It assumes human cognition and behavior as embedded in collectively organized, artifact-mediated activity systems (Cole & Engestrom, 2007; Engestrom, 1987; Leont'ev, 1978). Learning is conceptualized as interactions and negotiations between individuals, humans, or nonhumans (e.g., mobile technologies), which occur in the form of evolving states of knowing as they are shaped by continuously negotiated goals in the changing contexts. The mobile technology provides a shared conversational learning space on the move, which can be used not only for single learners but also for learning groups and communities. The technology can also be utilized to demonstrate ideas or proffer advice, as with the Internet or through specific tools to negotiate agreements, such as concept maps and visualization tools. Other studies (e.g., Liaw, Hatala, & Huang, 2010; Wali, Winters, & Oliver, 2008; Waycott, Jones, & Scanlon, 2005; Zurita & Nussbaum, 2007) have also grounded and conceptualized m-learning using activity theory.

Laurillard (2007) proposed using a conversational framework to investigate how mobile technologies can contribute to the learning process. Regarding collaboration, the conversational framework holds that learners will be motivated to improve their collaborative practices if they can share their products with peers, and to enhance their conceptual understanding if they can reflect on their experiences by discussing their products with peers. Such a view is congruent with that advocated in So, Seow, and Looi (2009) and Wong, Chen, and Jan (2012), that students' contextualized artifacts created in situ (e.g., during a teacher-facilitated field trip) have the potential to go beyond facilitating just-in-time knowledge sharing to mediating future knowledge coconstructions. This requires that the teacher set up motivating collaborative and competitive tasks for the students, who will be motivated by the prospect of contributing to a product or artifact as part of the learning process. A typical collaborative m-learning activity can provide more opportunities for digitally facilitated site-specific collaboration, and for ownership and control over what the learners do jointly, because the mobile devices digitally facilitate the link between the students and the data/products on the spot. However, Sharples et al. (2007) posited that, because the Conversational Framework describes conversations for learning situated in one physical location, it does not address adequately the challenging issues of the constantly negotiated communication and interaction in the continually changing context in mCSCL.

Notwithstanding these theorizations of m-learning in the context of an activity system and Conversational Framework, large numbers of mCSCL studies have adopted "folk theories" based on commonsense assumptions in interpreting the results of interventions for collaborative learning, as if there were no need for theory (Stahl & Hesse, 2010), while much less research has attempted to delve into and refine theoretical perspectives specific to mCSCL. It is high time to rediscover mCSCL. What does mCSCL mean? What are the pedagogies and methodological issues of mCSCL? These are the questions that confront us, and that are hard for us to answer, yet need to be discussed.

## MCSCL

### *What Does mCSCL Stand For?*

Does mCSCL stand for "mobile + CSCL"? Our answer is "Yes" and "No." The evolution of mobile technology is believed to be part of the fourth wave computer technology that will deliver anywhere, anytime learning (Pownell & Bailey, 2002). Thus, if we try to understand the acronyms of mCSCL literally, our answer is "Yes": it stands for mobile-computer supported collaborative learning. However, if we attempt to understand practices of mCSCL, our answer is "No": it does not simply mean that the differences in the practices of CSCL and mCSCL lie in the word *mobile* added to the front of CSCL, but lie in the changing practices that "mobile" technologies have contributed to.

### *Characteristics and Affordances of Mobile Technologies*

To understand the changes regarding mCSCL practices caused by mobile technologies, it is important to be clear about the characteristics and affordances of the technologies that are new and different from computer (desktop and laptop) technologies. Many researchers have expressed the belief that mobile technologies can potentially have a great impact on the ways of practice as a result of their portability/mobility, immediate accessibility, and connectivity (Klopfer, Yoon, & Rivas, 2004; Norris & Soloway, 2004; Segall, Doolen, & Porter, 2005). In particular, the portability of mobile devices is considered to be a significant factor that contributes to collaborative learning because it can help students to coordinate and interact in joint projects and share resources over the mobile devices more readily (So, Seow & Looi, 2009; Zurita & Nussbaum, 2004). The immediate accessibility offered by mobile devices is considered to be one of the greatest benefits for both teachers and students (Ally, McGreal, Schafer, Tin, & Cheung, 2008). Using the devices, data can be collected, stored, and organized easily, and the information can be searched, posted, and shared instantly (Ally et al., 2008; Crowe & van't Hooft, 2006; Sharples et al., 2007).

Another characteristic of mobile devices is connectivity. Now the evolution of computing, using mobile devices with new types of wireless connectivity, allows collaborative learning to happen anytime, anywhere. This changes the rules of technology use, both in and out of the classroom. With connectivity, communication between students and the tutor, and among peers, is enhanced via a package of communication tools such as short messaging service (SMS), e-mails, phone calls, communication systems, and the Internet (e.g., Markett, Arnedillo-Sanchez, Weber, & Tangney, 2006); valuable information and resources can be shared via file exchanges between mobile devices using Bluetooth or Infrared port "just-in-time" (e.g., Lai & Wu, 2006); and coconstruction of knowledge among students and online learning communities can be improved via online chat tools such as MSN messaging and forums (So, Seow, & Looi, 2010). Although interactivity, individuality, and context sensitivity (e.g., Cui & Bull, 2005; Markett et al., 2006) have also been considered to be characteristics of mobile devices, mobility, accessibility, and connectivity are the essential features that make all other characteristics possible. In addition, interactivity is not unique to mobile technologies.

Affordances coexist with constraints (Conole & Dyke, 2004). Mobile technology educational research has also revealed a host of technical constraints. The main constraints include the small screen sizes of mobile devices, a lack of standard platforms among different devices, problems in browsing websites, lack of ubiquitous connectivity, difficulties in writing input, and lack of computational power.

The affordances and constraints of mobile technologies influence the possibilities for collaboration. Different types of mobile devices offer different form factors and mobility affordances. The mobility of a device and its weight (from hand-held smart phones to tablets to Netbooks to notebooks), along with the form factor of mobile devices, afford and constrain the potential for CSCL. However, a small screen size does not have to be a barrier to collaborative work. For example, small screen displays do afford multiple users viewing their displays and seem to support more cooperative styles of working when partners have their own activities to complete, but come together periodically to share digital information (Stanton & Neale, 2002). mCSCL software tools can have forms of interface design that allow children to collaborate around a mobile device or devices which coordinate the interaction among them and enable them to share their responses and other information (Zurita & Nussbaum, 2004). In particular, Rogers, Connelly, Hazlewood, and Tedesco (2010) viewed the small form factor as an opportunity to facilitate new learning models or habits—with the devices to be used for short bursts of time (e.g., entering and comparing data, looking up and reviewing information, brief communication and sharing of artifacts with peers and remote people) to support foregrounded physical activities in situ.

The mobile devices of relatively smaller form factors may still make the relatively "complex" and in-depth knowledge synthesis and knowledge coconstruction activities rather tedious if the learners are using mobile devices solely to perform these tasks. For example, it is difficult even for a single learner to create a concept map with more than 20 nodes using a smart phone, not to mention if a collaborative concept mapping task is to be carried out by a group of students through their smart phones. With this, Wong and Looi (2011) advocated a "division of labor" strategy, with each student keeping one smart phone and one netbook or laptop at hand to handle the needs of various formal and informal, planned and incidental learning tasks. The small size and light weight of smart phones make them the perfect tool for students to perform quick and rapid learning tasks on the move, including scripted or spontaneous communication or collaboration among members of the learning community (students, teachers, etc.). Whenever students have the chance to sit down (either during a field trip, on public transport, in the library, in the park, or at home), the netbook or laptop (or perhaps school or home PC) will compensate for the limitations of the smart phones by supporting them in carrying out more "complex" learning tasks such as detailed data analysis, learning collaboratively in 3D virtual environments, and knowledge building. Examples of prior mCSCL studies that adopted similar strategies were reported in So, Seow, and Looi (2008), Thompson and Stewart (2007), and Wong, Chin, Tan, and Liu (2010), with students making use of lightweight mobile devices for personal or collaborative in situ learning activities, and school or home computers for extended knowledge coconstruction over a relatively longer period of time.

## MCSCL PEDAGOGICAL DESIGN AND PRACTICES

This section summarizes current mCSCL pedagogical design and practices by categorizing them into three main types: in-class mCSCL, out-of-class mCSCL, and mCSCL that bridges both in-class and out-of-class activities. We also discuss the notion of a curricular activity system that might comprise learning activities of these three main types put together coherently to realize some curricular goals.

### *In-Class mCSCL Pedagogical Practices*

Roschelle (2003), focusing on the "key [classroom] communication issues" (p. 262) of mobile technologies that may affect pedagogic practices, classified collaborative activities into three types: classroom response systems (e.g., Davis, 2003), participatory simulations (e.g., Colella, 2000; Soloway et al., 2001), and collaborative data gathering (e.g., Vahey & Crawford, 2002). A classroom response system allows a teacher to pose a short answer or a multiple-choice question. The system instantly collects and aggregates all students' responses through their handheld devices (such as clickers, graphing calculators, WinCE handhelds, or special-purpose infrared beaming units). Facilitated through a 1:1 setting, a participatory simulation enables students to act as agents in simulations in which overall patterns emerge from local decisions and information exchanges. The system computes the simulation of a scientific phenomenon such as swarming ants, traffic jams, or the spread of disease. In collaborative data gathering activities, students use probes to gather and graph data from live experiments.

Looking back on Roschelle's publication almost a decade later, we found his classification is far from being exhaustive given the more diversified innovative designs in this area that emerged after the paper was published. Nevertheless, Roschelle had indeed highlighted three specific classroom-based mCSCL models that were developed in the early days of m-learning research which are otherwise impossible or tedious to be implemented without the deployment of mobile technology (specifically, a 1:1 setting is essential to facilitate the first two models). Conversely, in advocating their approach to future classrooms organized around wireless internet learning devices (WILD), Roschelle and Pea (2002) argued that CSCL should leverage application-level affordances such as augmenting physical spaces, leveraging topological spaces, aggregating coherently across all students, as well as the physical affordances of mobile devices.

One important study of in-class mCSCL tackled the use of mobile connected devices in classrooms for teaching young children how to collaborate (Nussbaum, Alvarez et al., 2009). In the CollPad system, students were given language and mathematics tasks they had to solve by working in fixed groups of three, with each student being equipped with a PDA. Figure 24.1 shows a pedagogical flow in which groups of three students, each working out their own solutions to a mathematics problem, collaborated and sought consensus with each other in the group and later in the class, with the teacher mediating and guiding classroom discussions.

In Syllable-mCSCL, a Spanish vocabulary-learning game for young children, the students were given language tasks that they had to solve by working in groups of three. A syllable is assigned by the system to each group member's mobile device (e.g., "si," "la,"

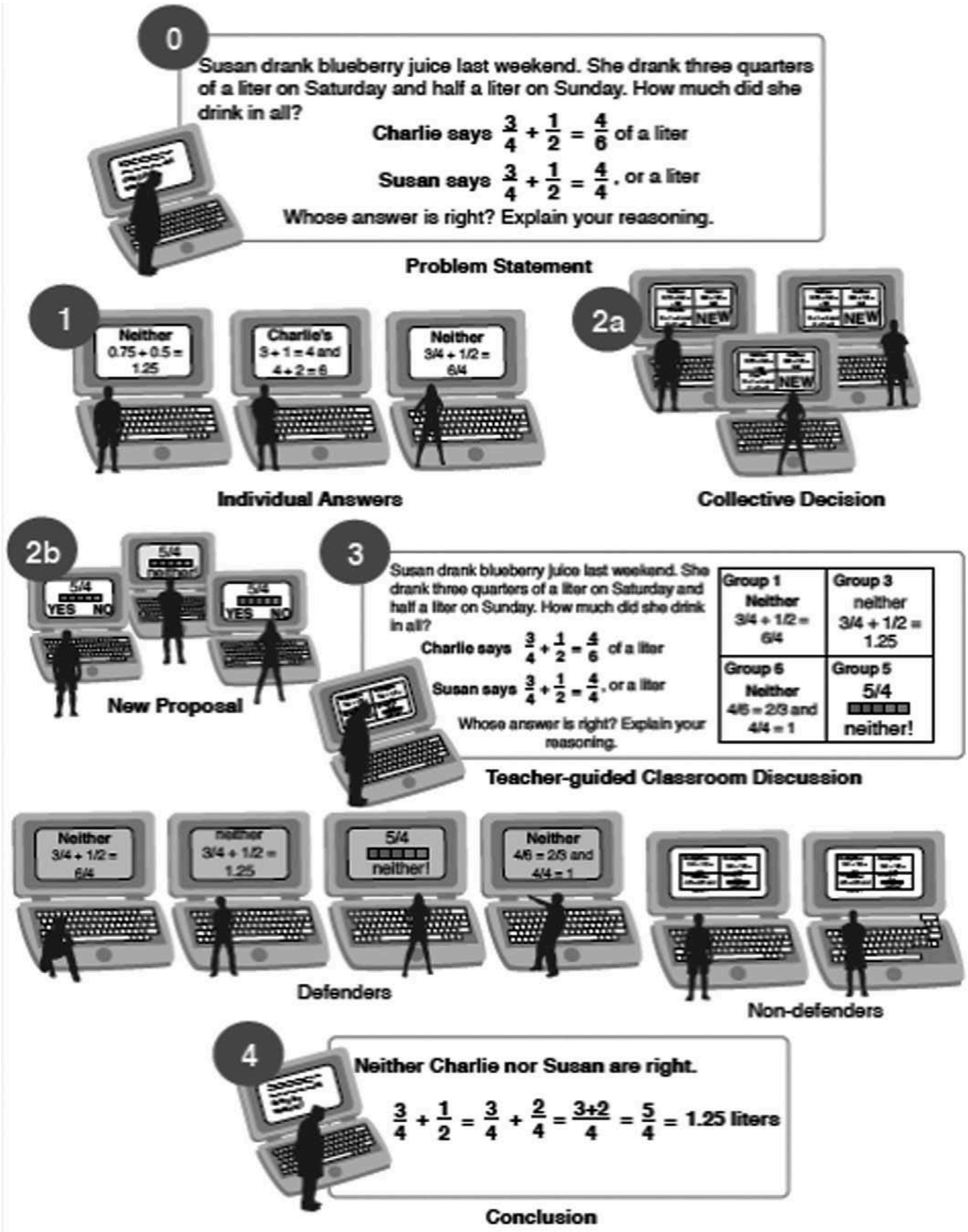


**Figure 24.1** CollPad system for mCSCL (we thank Miguel Nussbaum of providing this figure).

and "bi") and the three students within the group need to determine the sequences of the syllables to form correct Spanish words (e.g., "silabi"). In the process, they have to exhibit a certain level of interaction and communication in order to complete the group tasks. The authors reported that the use of wireless networks in the classroom opened up many educational possibilities and that mobile devices advanced various components of collaborative learning, namely the learning material organization, social negotiation space, communication between team members, coordination between activity states, and the possibilities for interactivity and mobility of team members (Kreijns et al., 2002).

These mCSCL practices extend the idea of mobile technology mediated learning with the collaborative scaffolding in order to include both social and epistemic collaboration scripts encouraging small-group participation (Nussbaum et al., 2009). The design of collaborative scaffolding encourages social interactions, facilitates joint problem solving, leads to richer knowledge construction, takes into account different and emerging roles, joint group goals and actions, and facilitates verbal explanations.

Inspired by Zurita and Nussbaum's body of work, Boticki, Looi, and Wong (2011) designed and developed Form-A-One (FAO), a game-based mCSCL approach with the salient characteristics of spontaneous group formation and the dynamic balance between collaboration and competition. The FAO approach was instantiated in two domains—mathematics and Chinese Language learning. In the mathematics game, each student receives a different fraction and has to find other students with fractions to form a whole of one. In the Chinese Language game (Wong, Boticki, Sun, & Looi, 2011), each student receives a different component of a Chinese character, and has to find other students with components that form legitimate Chinese characters (Figure 24.2). Students have to achieve local goals (maximizing individual group size) and a global goal (minimizing the number of peers who are unable to form groups or even disbanding groups to form new combinations with others).

The Zurita and Nussbaum mCSCL learning model and Boticki, Looi, and Wong's FAO are based on the common idea of disseminating domain-specific components to

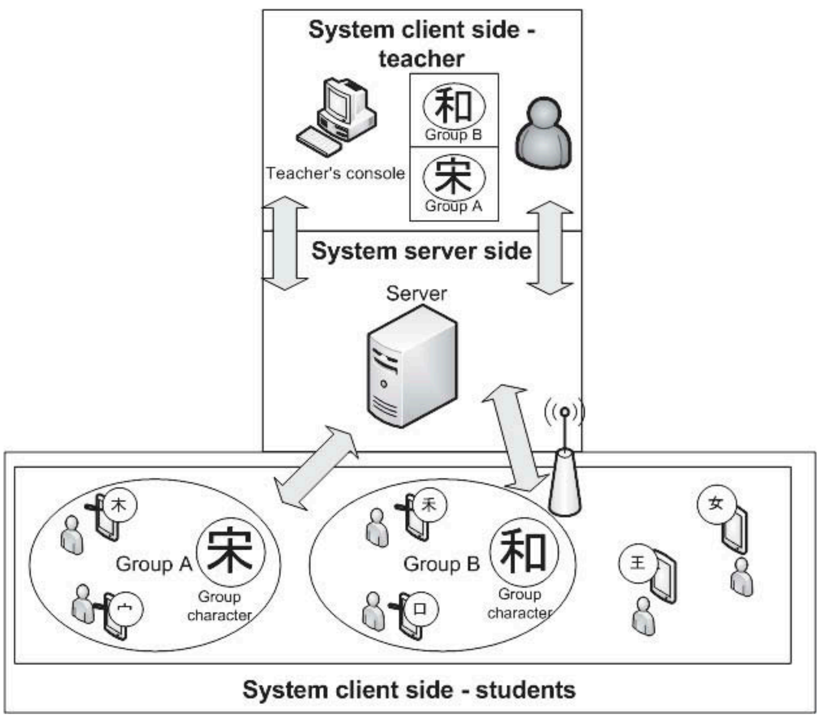


**Figure 24.2** Students collaborating to form Chinese characters in mCSCL.

individual students through their mobile devices and requiring them to piece the components together to achieve certain objectives. Indeed, both learning models can also be implemented through non-mCSCL means, such as using cards or paper tokens or using stable technologies (e.g., personal computers) in 1:1 settings. However, it is the mCSCL solution that brings together the mutually exclusive but complementary advantages of the two alternative settings. The mCSCL solutions may free students and teachers from dealing with cumbersome physical resources and, instead allows them to focus on the sociocognitive process, or (for teachers) orchestrating the learning process "globally," as well as ensuring a mixture of face-to-face and mobile technology mediated communication for greater social interactivity.

In-class mCSCL typically augments the conventional face-to-face communication and collaboration of physical classrooms with a layer of networked communication through devices. Face-to-face collaboration is not necessarily obsolete as a result, but its forms might be changed or simplified. For example, in FAO games (Boticki et al., 2011), although a student can identify and invite peers to form a group via the device, more sophisticated negotiations (e.g., for optimizing the groupings), as well as the teacher's domain-specific scaffolding, may still need to be carried out face-to-face when such needs arise. In collaboration over mobile devices, the device can serve as a cognitive tool, as a productive tool, as a data retrieval or context sensing tool, or provide the means to use existing collaboration tools like Web 2.0, SMS/MMS, IM, or Group Scribbles.

### *Out-of-Class mCSCL Activities*

Congruent with the notion of situated, experiential, social, and inquiry views of learning, field trips and outdoor activities are well-established activities for many schools. With the incorporation of mobile equipment, the trip facilitators, such as teachers, are in a better position to strike a balance between ensuring a learner-centered experience (e.g., using mobile technologies to access context-sensitive multimedia information, reflective data collection and processing, augmented reality, and communication with peers or teachers) and external moderation or scripting (e.g., field trip management and scaffolding), through flexibility, spontaneity, and adaptability in mobile settings (Frohberg, 2006).

In the social aspect of mobile-assisted out-of-class learning, mobile technologies provide a vehicle for multiple conversations to take place, and more opportunities for students and their instructors to verbalize and reflect upon their inquiries (Chan et al., 2006; Rogers & Price, 2009). Nevertheless, museum visitors or learners using mobile devices tend to focus their attention more on the mobile devices than on interacting with the physical environment and each other (Hsi, 2003; Spikol & Milrad, 2008).

Therefore, researchers have been designing situated mCSCL activities with explicit requirements for collaborative efforts, either over the device via face-to-face communication, such as Ambient Wood (Rogers & Price, 2009) and LET'S GO! (Maldonado & Pea, 2010), or through the device, as in the Bird-Watching Learning system (Chen et al. 2003). A particular design requires separate groups of learners located at different parts of a site (or at multiple sites) to collect and share information on-the-fly in order to achieve certain learning goals such as AMULETS (Kurti, Spikol, & Milrad, 2008) and Laborador Trail (Wong, Chen, Looi, & Zhang, 2010). Such learning designs, which are made possible by the mobile technology, are rooted in the notions of distributed cognition (Hutchins, 2000) and positive interdependence (Johnson & Johnson, 1992). For example, in the AMULETS activity, students in the outdoor group can explore the old city area of Vaxjö, Sweden, and collect cultural, historical, and geographical data (such as photos of ancient buildings) with their smart phones. The data can then be transmitted to the indoor group of students stationed in a local museum and equipped with laptops for further processing.

Similarly, in Labrador Trail, where students visit some World War II military infrastructure within Labrador Park, Singapore, several scripted tasks are introduced to reinforce mCSCL activities throughout the field trip. One such example pertains to a hole in the ceiling of a restored tunnel where former soldiers inside the tunnel could transfer ammunition by means of a hanging rope to their counterparts who were operating a battery on top of the tunnel. Two different student groups, who have not been told about the functionality of the hole, are led to the battery and the tunnel respectively. They are asked to take videos and share with each other via a moblog in order to piece their observations together and deduce the use of the hole. It is the collaborative inquiry process that both designs bring forward to the students in order to foster their awareness and capabilities in collaboratively collecting, analyzing, and synthesizing data and knowledge, with the aid of the mobile technology.

### *Bridging In-Class and Out-of-Class mCSCL Activities*

Bridging the sharp boundary between formal and informal learning, as elaborated by Chan et al. (2006), is "to extend formal learning time, usually limited to the classroom, into informal learning time, to embrace opportunities for out-of-school learning driven by the personal interests of students" (p. 6). In delineating the boundary, some literature looks exclusively at the physical context—learning that occurs out of the classroom or school compound, including teacher-planned field trips, which is considered informal learning (e.g., Spikol & Milrad, 2008; Vavoula et al., 2009). Other literature has looked into who is in control of the learning goals and content—only student-initiated learning or incidental (unintended) learning is regarded as informal learning (Looi, Zhang et al., 2011), while teacher-planned field trips can be characterized as "formal learning in informal settings." Mann and Reimann (2007) referred to the two types of informal learning as "non-curriculum-oriented informal learning" and "curriculum-oriented informal learning."

Examples of mCSCL activities bridging formal and informal learning are students carrying out teacher-instructed learning activities beyond the formal class time or teacher-led outdoor learning activities at their own convenience, such as online discussions (e.g., Huang, 2007), ongoing game playing (e.g., Metcalf, Milrad, Cheek, Raasch, & Hamilton, 2008), or data collection or artifact creation (largely incidental encounters or improvisations), sharing or peer reviews in daily life (e.g., Wong, Chin et al., 2010).

A seamless learning environment bridges private and public learning spaces where learning happens as both individual and collective efforts and across different contexts (such as in-school versus after-school, formal versus informal). Two seamless learning studies: SEAMLESS Project (Looi, Seow et al., 2010; Zhang et al., 2010) and "Move, Idioms!" (Wong, Chin et al., 2010; Wong & Looi, 2010) have focused on the *mobilization* of the formal science curriculum and Chinese idiom learning (with a "seamless language learning" construct) respectively. Student learning experiences have been designed in the form of cross-context learning flows that reinforce or encourage small student group collaborations in classroom or field trip settings, student–parent interaction or collaboration such as artifact cocreation or "teaching the parents" activities (Looi, Zhang, et al., 2011), and online peer reviews. The mobile devices mediate all the activities by assuming the role of a personal "learning hub" (Looi, Wong, et al., 2009) to support students' seamless learning experiences, including their blending into various social learning spaces. From the seamless learner's point of view, the individual experiences seamlessness when switching contexts between different learning activities (Wong, 2012; Wong & Looi, 2011).

### *Curricular Activity Systems that Incorporate mCSCL*

We use the notion of a curricular activity system as the minimal unit of "impactful, adoptable" packaging of technology for a school (Roschelle, Knudsen, & Hegedus, 2010). In such an activity system, the activities are designed for teachers and students to enact and participate in. The responsibility for supporting such activities is distributed across technologies, software, paper curricula, teacher guides, and teacher professional development workshops. The designers of a curricular activity system seek to engineer an aligned set of related components that support the desired curricular activities coherently. Thus teacher professional development, curriculum materials, software documents, and so on are all designed together with a system perspective toward enabling classroom realization of the intended activities. It is in this context that we look at learning designs that incorporate mCSCL activities. Curricular activity systems in the classroom may include elements of in-class mCSCL, out-of-class mCSCL as well as seamless mCSCL, thus broadening the notion of curricular activity systems to learning activity systems where the context may also be out-of-class.

In a curricular or learning flow system, the mCSCL component may enable initial in-context interaction, and content delivery and creation that can stimulate further meaning-making (Kukulska-Hulme, Sharples, Milrad, Arnedillo-Sanchez, & Vavoula, 2009). For example, the mCSCL component allows the learner to tag areas of interest and create context annotations that can lead to further follow-up learning using desktop PCs in fixed spaces.

One approach to designing curricular activity systems that incorporate mCSCL is to situate the use of mobile technologies to support various forms of cooperative/collaborative learning like jigsaw, brainstorming, reciprocal teaching, problem-based learning and other collaborative scripts. Here, we take mCSCL-based jigsaw, arguably the best-known collaborative script, to exemplify how the synthesis of m-learning and "conventional" collaborative learning scripts can take place to varied extents. Jigsaw shares some common features with distributed inquiry in which students need to exchange information to achieve certain learning objectives. Distributed inquiry requires different student groups to play different roles. In AMULETS, one group collects data in the outdoor setting and another processes the collected data in the indoor setting (Kurti, Milrad, & Spikol, 2008). In the Labrador Trail, the students exchange and discuss information in order to synthesize knowledge (Wong et al., 2010). In jigsaw activities, an individual who returns to her home group after working with her expert group only has access to a subset of the information necessary to solve the problem, and the entire group needs to piece up and process the information together (Aronson, 1978).

In the various studies on mCSCL-based jigsaw that were conducted in the past decade, the roles played by the mobile technology varied considerably. In Liu et al. (2003), and

Lai and Wu's (2006) designs, the mobile devices were used merely for Internet search, or creating and exchanging student artifacts, while the group discussions have been carried out face-to-face within the traditional classroom. In the jigsaw-scripted mCSCL field trip design of AnswerTree (Moore, Goulding, Brown, & Swan, 2009), students who explore different areas of a wood communicate with each other via phone calls and text messages. The Mobile Jigsaw project (Thompson & Stewart, 2007) aims to facilitate students to collect information about their local environment and which pertains to the topics assigned to their respective expert groups in order to create a database of plant species for subsequent home-group learning.

The diversified ways in which the "m" is incorporated into these mCSCL-mediated jigsaw activities can probably offer a "miniature" view of the roles that the mobile technologies play in facilitating CSCL in learning activities—as a reference tool and productivity tool (which does not foreground the collaborative aspect of the learning script) to authentic data capturing/repository and synchronous/asynchronous communication tools. mCSCL offers the potential for further collaborative knowledge construction but we argue that this aspect has not been analyzed well in typical m-learning literature, as m-learning researchers usually put greater emphasis on studying the aspects of mobility, context-awareness, or personalization in their designs.

### *New Methodological Challenges for mCSCL Research*

This section discusses new methodological challenges regarding methodological design and analysis in mCSCL research. In mCSCL educational research, a large number of mCSCL research studies have adopted quantitative approaches. Research methods used in these studies have employed instruments of pre- and posttests and questionnaire surveys with a small number of participants (e.g., Huizenga, Admiraal, Akkerman, & ten Dam, 2009; Lan, Sung, & Chang, 2007; Yin, Ogata, & Yano, 2007). Surveys with closed questions, seeking to understand the behaviors or attitudes of participants toward mobile technology educational applications, have been prevalent (e.g., Corlett, Sharples, Bull, & Chan, 2005; Lai & Wu, 2006). However, it has been claimed that open-ended questionnaire items have far greater credibility in terms of the results they produce than quantitative ones based on survey data (Patton, 2002). Some studies have claimed to have adopted mixed research methods, but, in fact, a questionnaire survey has been the dominant means of data collection (e.g., Motiwalla, 2007). Moreover, if only a few participants have been involved in a study, it challenges the value of conducting surveys as one of the mixed methods (e.g., Swan, van't Hooft, Kratcoski, & Unger, 2007).

Some studies have addressed research problems through qualitative approaches, but, in many cases, the studies have been carried out over short periods of time, and only used single data collection instruments, such as interviews, or video data (e.g., Lan, Sung, & Chang, 2007). Therefore, the credibility of the research may be challenged due to lack of data triangulation (e.g., Creswell, 2008).

Traxler and Kukulska-Hulme (2005) pointed out that "many of the trials and pilots themselves rest on a 'common sense' view of learning" (p. 7) without using much theoretical justification or coherence to support the research methods or techniques. Although the research findings have generally been positive, this may result partly from a "strong novelty effect" which refers to the phenomenon of participants being highly motivated to use new technologies to support their studies due to great interest and curiosity in using these technologies (Thornton & Houser, 2005, p. 224) or the "Hawthorne effect"

(Swan et al., 2005, p. 110) which refers to the phenomenon that participants report what they think researchers expect to hear or see, not what is actually happening.

Generally speaking, currently, well-designed research studies on mCSCL are still scant. Methodologies adopted in much of the current mCSCL educational research rely largely on small-scale, short-term trials or pilot studies using quantitative approaches. Studies using qualitative approaches exist but usually these have been carried out over short periods of time, and data collection methods have been limited to using interviews as major means of data collection. These issues are also prevalent in research on other forms of m-learning and on other technology supported learning environments. New methodological issues arise with the emerging research area of mCSCL.

For mCSCL studies that bridge formal and informal contexts, new methodological challenges emerge such as the need for data collection methods that can capture mCSCL processes and outcomes in continually moving and re-constructed contexts. Learners may carry and use their 1:1 mobile devices as their personalized devices to do a range of activities, only some of which may be relevant for the analysis of mCSCL interactions. The characteristics of mCSCL data may be their lightweight nature when captured on mobile devices or their potential to be distributed over interactions spanning digital and face-to-face, and artifacts that are spread out in the switching contexts in which the learner happens to be. The distributed and sparse nature of interactions through and over mobile devices poses a challenge for tracing the uptake of ideas and idea development processes.

Learners may become more and more engaged in personalized learning as part of a bigger context of learning flow. How does such personalized learning contribute to mCSCL? What may be the qualitative research methods available for such analysis? How do we analyze individual learning, group learning, and community learning in the learner generated contexts? These are the new conceptual and methodological challenges for studies in mCSCL.

Nevertheless, current studies have paved the way for further research on mCSCL by adopting methodologies such as design-based research (DBR) (e.g., Lan et al., 2009; Roschelle, Rafanan, Estrella, Nussbaum, & Claro, 2010). DBR refers to an iterative process of designing, experimenting, reflecting upon, and redesigning the learning model and applications, and to integrating design principles with technological affordances to render plausible solutions. While experimental design (experimental vs. control) is more useful for lab-based studies, DBR examines school and classroom practices which are situated in complex learning environments where it is difficult to hold variables constant. Typically, design-based researchers have tried to optimize as much of the design as possible and to observe how the different variables and elements are working out (Barab & Squire, 2004; Collins, Joseph, & Bielacyzc, 2004). For instance, Wong, Boticki, et al. (2011) described the first DBR cycle of their mCSCL study where the (class-) cultural, behavioral, cognitive, and subject matter-specific factors were observed in the preliminary trial runs of the game-based learning activities. These factors informed the rigorous revision of their game rules, CSCL scaffolds, and software user interface design. The DBR methodology allows researchers to collect and analyze data to multiple mCSCL factors simultaneously and to use the rich data to improve a design iteratively than might be accomplished through systematic experimentation on each individual factor (Design-Based Research Collective, 2003).

## CONCLUSION

mCSCL, as a specialization of the field of CSCL, alleviates the condition of fixed times, spaces, locations, and topics for doing collaboration activities. By employing mobile devices, learning becomes personal and mobile, and students are able to participate in collaborative learning activities whenever and wherever they want to (Looi, Seow, et al., 2010). Students leverage on their own mobility and the mobility of the devices in order to coordinate collaboration and to construct or build knowledge over the wirelessly connected devices. Some prior mCSCL designs have incorporated knowledge construction components that either take place after certain teacher-facilitated field trips or intertwine with learners' informal learning activities (typically carried out in their own time). Such integrative activities are usually performed by using school or home computers instead, in order to overcome the form factor constraint caused by the complexity of the tasks.

We also emphasize the embedding of mCSCL activities in a broader curricular or learning flow system in which mCSCL supports in-context interaction and context delivery and creation, as well as time and space for personalized and social learning. As our review shows, there are in-class mCSCL studies in which the learning design and practices do foreground collaborative learning as a process and outcome of learning. The current studies for m-learning, which incorporate a strong element of mCSCL for out-of-class and for bridging both in-class and out-of-class, do not seem to necessarily foreground analysis of collaborative learning processes and outcomes. We argue that such a phenomenon can be attributed to the underlying difference between the major interests of the researchers in m-learning and the CSCL communities; general m-learning researchers usually focus on the study of learning mobility, contextualization/situated*ness* of learning, or personalization of learning as their overarching research inquiries.

This phenomenon is also due partially to difficulties in tracking and collecting CSCL data when learning takes place on the move or across a long period of time in constantly switching contexts. Therefore, mCSCL is usually incorporated as a significant component of these studies but the collected data are rarely analyzed in a rigorous manner (e.g., discourse analysis or social network analysis) as typical CSCL research does. Herein lies a research challenge for mCSCL. It is our hope that this book chapter can stimulate a dialogue between the m-learning and CSCL research communities. The m-learning community can extend its focus on the mobility of the learning environment to generating and analyzing productive collaborative human interactions resulting from such mobility. The CSCL community can start to investigate new methodologies and approaches to study an amalgam of data sources that arise in different contexts, modalities, and time periods.

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