Methodological Issues in Mobile Computer-Supported Collaborative Learning (mCSCL): What Methods, What to Measure and When to Measure?

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ABSTRACT
This study aims to investigate (1) methods utilized in mobile computer-supported collaborative learning (mCSCL) research which focuses on studying, learning and collaboration mediated by mobile devices; (2) whether these methods have examined mCSCL effectively; (3) when the methods are administered; and (4) what methodological issues exist in mCSCL studies. It attempts to bring to light methods more conducive to examining the effectiveness of mCSCL and thus to sustain the practices. The research findings reveal a variety of methodological issues that need to be addressed. Comparison is made to the findings in CSCL research and other studies leveraged by mobile technologies. Potential ways to investigate the effectiveness of mCSCL practices are proposed.

Keywords
mCSCL, Methods, Measures, Methodological approach

Introduction

Computer-supported collaborative learning (CSCL) research is concerned with studying how people can learn together with the help of computers as an emerging field of learning sciences (Stahl, Koschmann, & Suthers, 2006); while Mobile Computer-Supported Collaborative Learning (mCSCL) research focuses on learning and collaboration mediated by mobile devices (e.g., Zurita & Nussbaum, 2004). Stahl et al. (2006) maintain that it is a challenging task to combine the two elements “computer support” and “collaborative learning” to effectively enhance learning that CSCL is designed to address. Yet, it is an even more challenging task to understand how to combine the ideas of “mobile computer support” and “collaborative learning” to advance learning and collaboration in different settings and modes because mCSCL involves many changing practices partly due to the unique technology characteristic of “mobility” and the dynamically re-constructed context for interaction and learning (Looi, Wong, & Song, 2012; Arrigo, Kukulska-Hulme, Arnedillo-Sánchez, & Kismihok, 2013). Various tools and systems have been increasingly developed on, or integrated into, mobile devices for mCSCL. These activities have been carried out across different spaces physically, socially and virtually. However, despite a number of studies reporting the benefits gained from the implementation of mobile tools or systems for mCSCL, little impact has been observed on actual educational practices outside the context of research investigations (Roschelle et al., 2010). To uncover the “black box” of mCSCL research, it is crucial to explore current mCSCL research designs, especially current methodology approaches to mCSCL practices in order to understand how groups and individuals make sense of situations and construct knowledge supported by mobile technologies, and what methodological issues are unique to mCSCL practices. Thus, this study attempts to conduct a systematic review of methodological approaches found in the mCSCL research literature in order to bring to light potential methods more conducive to examining the effectiveness of mCSCL practices, and to uncover methodological design issues in mCSCL practices to be addressed in future research. This, in turn, will help sustain the practices.

This paper first provides a description of how the literature review was carried out. Second, the results of the review are presented followed by discussions of methodological issues and potential directions for future mCSCL research. Finally, conclusions are drawn.

Method

To understand mCSCL practices, a systematic review was carried out. A systematic review refers to a review of the literature based on explicit, rigorous and transparent methodology (Coffield, Moseley, Hall, & Ecclestoneaims, 2004). This study systematically reviewed and synthesized the relevant literature on mCSCL research to unpack the methodological approaches adopted in the studies (Coffield et al., 2004; Wong & Looi, 2011; Wu, Wu, Chen, Kao, Lin, & Huang, 2012). In general, the first phase of a systematic review is framing the research questions regarding
which the review is carried out. This is followed by a thorough search of the relevant literature, followed by a check of the criteria in selecting articles that meet the review purposes. The second phase is the review process. Finally, the third phase is to write the report of the review. The review is intended for researchers who are interested empirical studies in the area of mobile/handheld educational applications, especially methodological issues in mCSCL practices.

The research questions are:
- What methods are utilized in mCSCL research?
- When are the methods administered?
- Have these methods examined mCSCL effectively?
- What issues do the methodological approaches have in existing mCSCL studies?

**Selection criteria**

To address the research questions, a set of criteria drawn from the literature (e.g., Gress et al., 2010; Hsu & Ching, 2013; Wong & Looi, 2011) was used in selecting articles that met the review purposes. These criteria are: (a) mCSCL studies that have addressed group collaboration supported by mobile technologies; (b) empirical studies, including case studies and evaluation studies with empirical evidence; (c) studies that have explicit research questions/statements; (d) studies that include handheld devices which refer to mobile devices that are small, handheld computing devices, typically having a display screen with touch input (http://en.wikipedia.org/wiki/Mobile_device), and are considered having strong a “mobility” nature such as PDAs, Smartphones, iPad, and mobile phones; and (e) studies published in refereed journals. In this review, studies that have used laptop computers to support collaboration are excluded because they do not belong to “handheld devices.” In addition, studies that are concerned mainly with conceptual frameworks, literature reviews, and technical infrastructures are beyond the focus of this review, and are excluded.

**Identification of eligible mCSCL studies**

The literature search and review underwent three stages. First, an extensive literature search was conducted in 33 major refereed academic journals related to technology-enhanced teaching and learning research, starting from the year 2000 when mobile educational research was at its infancy to February 2014 when this review work initiated. As this review focuses on studies of mCSCL that provide empirical evidence, refereed journals emphasizing mobile technological architecture design are excluded. In addition, articles from conferences and workshops are not included due to issues of inaccessibility or similarity of conference reports and journal articles. The search used the key words “mCSCL,” or “mobile computer-supported collaborative learning,” and “mobile” and “collaborative learning.” These journals were: Australasian Journal of Educational Technology, British Journal of Educational Technology, CALL (Computer-Assisted Language Learning), Computers & Education, Computers in Human Behavior, Educational Technology & Society, Educational Research Review, Educational Review, Educational Media International, Educational Technology Research and Development, ELT Journal, Instructional Science, International Journal of Computer-Supported Collaborative Learning, International Journal on E-Learning, Interactive Learning Environments, International Journal of Lifelong Education, International Journal of Science Education, International Journal of Technology in Teaching and Learning, Internet and Higher Education, Journal of Computers in Mathematics and Science Teaching, Journal of Computer Assisted Learning, Journal of Educational Computing Research, Language Learning & Technology, Learning and Instruction, RECALL, Research and Practice in Technology Enhanced Learning, Review of Educational Research, Technology, Pedagogy and Education, The Asia-Pacific Education Researcher, The Interdisciplinary Journal of E-Learning and Learning Objects, TechTrends, and The Journal of Learning Sciences. As of February 2014, the search of the publications in these journals yielded 122 results, among which, 31 articles met the criteria. A second round of search was conducted in GoogleScholar using the same key words as the literature search in refereed journals. The first ten pages of search results on GoogleScholar of each key word combination were viewed, from which 3 more articles were added to the pool. Finally, a third round of search used the snowball sampling approach (Gao, Luo, & Zhang, 2012) by scanning references cited in previous selected articles. One more article was identified and added to the pool. As a result, 35 papers were identified as eligible articles for the review and analysis (see Figure 1).
The process of identifying eligible mCSCL studies

The distribution of eligible articles is spread among 15 journals which are shown in Table 1.

Table 1. Distribution of eligible articles in all referred journals

<table>
<thead>
<tr>
<th>Journal name</th>
<th>No.</th>
<th>Journal name</th>
<th>No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Computers &amp; Education</td>
<td>9</td>
<td>Computers in Human Behavior</td>
<td>1</td>
</tr>
<tr>
<td>Educational Technology &amp; Society</td>
<td>7</td>
<td>Language Learning &amp; Technology</td>
<td>1</td>
</tr>
<tr>
<td>Interactive Learning Environments</td>
<td>4</td>
<td>Computer Assisted Language Learning</td>
<td>1</td>
</tr>
<tr>
<td>British Journal of Educational Technology</td>
<td>3</td>
<td>Journal of Science Education and Technology</td>
<td>1</td>
</tr>
<tr>
<td>Journal of Computer Assisted Learning</td>
<td>3</td>
<td>Asia-Pacific Education Researcher</td>
<td>1</td>
</tr>
<tr>
<td>Journal of the Learning Sciences</td>
<td>1</td>
<td>Educational Media International</td>
<td>1</td>
</tr>
<tr>
<td>International Journal of Computer-Supported</td>
<td>1</td>
<td>Research and Practice in Technology Enhanced</td>
<td>1</td>
</tr>
<tr>
<td>Collaborative Learning</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Analysis of mCSCL studies

This analysis has been illuminated by the review studies and commentary on examining measurement and assessment in CSCL and mCSCL review studies (e.g., Hmelo-Silver & Bromme, 2007; Gress, Fior, Hadwin, & Winne, 2010; Looi et al., 2012). According to Hmelo-Silver and Bromme (2007), measurement and methodological approaches are dependent on the theoretical framework being used and the research questions being asked. Measurement in CSCL can take one of the three forms: assessing the individual about the individual’s experience (assessing the individual learning process and outcomes), assessing the individual about the group’s experience (assessing the individual learning process and outcomes contributed to the group collaborative learning), and assessing the group as a whole (assessing group’s learning process and outcomes) (Gress et al., 2010; Hmelo-Silver & Bromme, 2007). Measurement in CSCL includes observing, capturing and summarizing both individual and group behaviors, from which researchers infer learning processes and outcomes. Factors affecting measurement in CSCL consist of individual differences, context, tool use, collaborative activities, and researchers’ different theoretical backgrounds (Gress et al., 2010). Because of the mobility nature of mobile devices, collaborative learning may occur in constantly changing contexts (e.g., from physical to virtual, from individual to social, and from informal to formal learning spaces). Thus, it is a very demanding task to capture the students’ learning process. For example, Song (2014) reported on a study of a collaborative science inquiry on the topic “Anatomy of fish” supported by mobile devices in a primary school. The pedagogical design included learning activities across different spaces – at home where students were asked to explore information about fish in a web market and online; in the school lab where students observed real fish brought by the teacher for each group; and in class and on a social network platform where students shared their findings and reflections. Hence, students learning experiences were not constrained to one place but occurred in constantly changing situations, which made tracking students’ learning trails a challenging task. To understand mCSCL practices, we need to examine holistically and “re-construct” (Avouris et al., 2007, p. 248) learning scenarios occurring in different contexts. To demonstrate how the mCSCL environment and tools benefit learning, it is essential to focus on methodological approaches (instruments/techniques), measures and analysis (Gress et al., 2010; Hmelo-Silver & Bromme, 2007). Based on the attributes of CSCL research, Gress et al. (2010) identify a coding scheme consisting of three key methodological aspects to be addressed: measures (e.g., efficacy and knowledge construction), methods (e.g., questionnaires, interviews, observations and discourse analysis), and measurement timing (e.g., assessment/evaluation timing before, during or after the collaborative task) in the CSCL context. Premised on Gress et al.’s (2010) coding scheme, to answer the present study’s research questions, an analysis framework was developed for the purposes of reviewing and analyzing mCSCL research. In the framework,
A new dimension “context of studies” was added by taking the “mobility” nature of mCSCL into account. Also, another element, “research design and foci,” was added. The framework consists of five elements: context of studies, research design and foci, methods, measures, and timing of measurement.

(a) Context of studies: This includes participants, sample size, duration of intervention, domain areas, adopted mobile technology/tools, and settings (in-class, planned/emerging; out-of-class, planned/emerging learning environments (Chen, Seow, So, Toh, & Looi, 2010; So, Kim, & Looi, 2008), and in-and-out-of-class mixed learning environments (Song, 2014)) which will be elaborated in a later section.

(b) Research design and foci: This relates to the research methodology adopted and research aims or statements in the studies. For example, Laru, Järvelä, and Clariana (2012) state that “The aim of the analysis was to identify and compare top- and low-performing dyads/triads in order to reveal the differences regarding their co-construction of arguments while creating knowledge claims” (p. 1).

(c) Methods: this refers to all the instruments such as questionnaires, surveys, discourse analysis, content analysis, and artifact analysis used in mCSCL research and techniques reported as used in the articles such as interviews, observations, discussions, and process data.

(d) Measures: these refer to dependent variables/subjects that are measured in the studies with the above instruments. Based on the research focus, the measures were more precisely identified. For example, the measure adopted in Laru et al. (2012) was co-construction of arguments.

(e) Timing of the measurement (before, during or/and after): this refers to the measuring/assessment timing (before, during, or after mCSCL practice) in the studies (Gress et al., 2010) (e.g., assessing students’ performance after collaboration in Laru et al., 2012). In addition, forms of measurement (assessing the individual about the individual’s experience, assessing the individual about the group’s experience, and/or assessing the group as a whole) are also examined (e.g., assessing the group as a whole in Laru et al., 2012).

Guided by the analysis framework, a content analysis of the 35 articles was conducted. The process of analysis consisted of four steps. The analysis framework together with the four-step analysis process across the entire study to address the four research questions is shown in Figure 2.

![Figure 2. Analysis framework and analysis process of the 35 eligible mCSCL studies](image-url)
intervention (1–5 days, 1–4 weeks, 5–8 weeks and > 8 weeks), domain areas (e.g., maths, science, etc.), adopted mobile technology/tools (e.g., smartphones, mobile learning systems/apps, others), and settings (in class, planned; out of class, planned, in and out of class, mixed, and others); (b) research design and focus (e.g., methods and the aims/objectives of studies); (c) methods (instrument/techniques such as questionnaires, surveys, interviews, observations, discussions and dialogue, feedback); (d) measures (dependent variables/subjects that are measured in the studies with the instruments, such as learning performance and collaborative learning behaviors/patterns); and finally (e) timing of the measurement (before, during, or after mCSCL practices).

The second step focused on identifying common themes of mCSCL practices and effects in the five dimensions across 35 articles to address the first two research questions (Q1: what methods? And Q2: when being measured?). Two researchers, based on the categories coded in the first step, independently coded the themes in the studies of the articles, and then compared and discussed the themes to reach consensus. The third step, based on the first two steps’ work, addressed the third research question (Q3: Have these methods examined effectively?). Finally the fourth step, based on the previous three steps’ work, addressed the fourth research question (Q4: What issues?). An example of the coding process is shown in Table 2.

<table>
<thead>
<tr>
<th>Coder 1</th>
<th>Research focus (RF)</th>
<th>Measures (M)</th>
<th>Methods (I)</th>
<th>Timing (T)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Improve collaborative learning approaches (#RF2)</td>
<td>Collaborative behaviors (#M2); metacognitive strategies (#M3); prior knowledge (#M5)</td>
<td>Observations (#I2); performance and products (#I6)</td>
<td>Before (TB), during (TD), after (TA)</td>
<td></td>
</tr>
<tr>
<td>Evaluate the effectiveness of learning system (#RF3)</td>
<td>Learning performance (#M1); metacognitive strategies (#M3)</td>
<td>Observations (#I2); process data (#I4); performance and products (#I6)</td>
<td>Before (TB), during (TD), after (TA)</td>
<td></td>
</tr>
</tbody>
</table>

**Consensus (after discussion)**

| Evaluate the effectiveness of learning system (#RF2) | Learning performance (#M1); Collaborative behaviors/patterns (#M2); Metacognitive strategies (#M3) | Observations (#I2); Process data (#I4); performance and products (#I6) | Before (TB), during (TD), after (TA) |

**Results**

**Research question (1): What methods are utilized in mCSCL research?**

To answer this question, Context of studies, and research design and foci were first identified, from which methods of mCSCL learning practices were distilled and categorized into 7 types. Further methods utilized in mCSCL practices were discerned in the course of content analysis of the 35 studies.

**Context of studies**

The context of the 35 studies are presented to provide a general picture of mCSCL practices. The context of a study influences the measurement of collaborative practices (Hmelo-Silver & Bromme, 2007). This is especially true in mCSCL practices (e.g., Hwang et al., 2011; Laru et al, 2012; Looi et al., 2012). The contexts of the 35 studies were categorized in terms of (a) participants, (b) sample size, (c) duration of intervention, (d) domain areas, (e) adopted mobile technology/tools, and (f) settings.

(a) Participants: Out of the 35 studies, 37 % was concerned with participants from primary schools, and 34 % and 29% were concerned with participants from tertiary education and secondary schools respectively.

(b) Sample size: Out of the 35 studies, 21 (60%) had sample sizes ranging from 10-50, and 2 (5%) had sample sizes smaller than 10, and 1 (3%) study did not mention its sample size.

(c) Duration of intervention: Almost half of the 35 studies (48%) had a research intervention ranging from 1 to 4 weeks. Ten studies (28%) had 1 to 5 days’ research interventions, which accounts for the largest percentage among all studies; and 2 studies (6%) did not report how long the intervention was involved.
(d) Domain areas: The domain area of 12 (29%) studies was science, followed by language (19%), IT related studies (19%), maths (17%), and others (7%). It is noted that all articles regarding IT related domain areas were conducted in tertiary education. In addition, 5 studies involved two to three subject areas.

(e) Mobile technology/tools: 13 studies (36%) chose smartphones as the mobile devices to support students’ collaborative study, followed by PDAs (34%), mobile phones (14%), tablets including iPad (8%), and others (8%).

(f) Settings: Researchers of mobile educational applications such as Chen et al., (2010) and So et al., (2008) classified the spaces where mobile learning happens into four types: (1) planned learning in class (e.g., Chinese language collaborative learning included in the curriculum in Wong et al., 2011); (2) planned learning out of class (e.g., field trips for science learning included in the curriculum in So et al., 2009); (3) emergent learning in class (e.g., new vocabulary look-up using mobile device in class that is not included in the planned activities in Song & Fox, 2008); and (4) emergent learning out of class (e.g., taking pictures using mobile devices out of self interest/motivation in Wong, Chen, & Jan, 2012). In this review, it is found that the majority of studies (65%) carried out the research in “planned learning in class,” followed by “planned learning out of class” (20%) and “planned learning in both in-and out-of-class” (15%). No research has reported findings regarding unplanned, “emergent learning out of class.”

Research design and foci

The research foci of the 35 studies were classified into five categories: (a) to improve the collaborative activity/process/learning using CSCL systems (12 studies, 34%); (b) to evaluate the effectiveness of learning systems/tools (10 studies, 29%); (c) to improve collaborative learning strategies/approaches (8 studies, 23%); (d) to explore the educational potential of learning systems/tools (4 studies, 11%); and (e) to discover collaborative learning patterns (1 study, 3%). It is noted that among the 35 studies, 15 of them (44%) adopted experimental or quasi-experimental design, followed by 6 (17%) studies employing a case study approach, 5 (14%) studies doing learning system evaluation, and five studies (11%) using design-based research approach.

Measures

Ten types of measures were identified (see Table 3). They are: learning performance (19%); collaborative behaviors/patterns (18%); prior knowledge/skills (16%); student satisfaction/attitude/perception towards learning system/tool (16%); metacognitive strategies (11%); process of collaborative investigations (10%); perception of learning skills (problem solving/ inquiry skills, collaborative skills) (3%); participation in collaborative activities (3%); self-efficacy and the local culture identity (2%); and affordances and limitations of collaborative learning system/tool (2%). Some of the studies had more than one measure to achieve their research aims.

Table 3. Ten types of measures identified in the 35 eligible studies

<table>
<thead>
<tr>
<th>Measures</th>
<th>Studies</th>
<th>n.</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Collaborative behaviors/patterns</td>
<td>Cortez et al., 2005; Zurita &amp; Nussbaum, 2007; Rogers &amp; Price, 2008;</td>
<td>12</td>
<td>19%</td>
</tr>
<tr>
<td></td>
<td>Roschelle et al, 2010; Chang &amp; Hsu, 2011; Hwang et al., 2011; Laru et al., 2012; Ryu &amp; Parsons, 2012; Lin et al., 2013; Sung et al., 2013; Song, 2014</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Learning performance</td>
<td>Zurita &amp; Nussbaum, 2004; Lan et al., 2007; Zurita &amp; Nussbaum, 2007; Lan et al., 2009; Liu et al, 2009; Capponi et al., 2010; Boticki et al., 2011; Wong et al., 2011; Lan et al., 2012; Timmis, 2012; Wong et al., 2012; Lin et al., 2013</td>
<td>11</td>
<td>18%</td>
</tr>
<tr>
<td>Prior knowledge/skills</td>
<td>White, 2006; Zurita &amp; Nussbaum, 2007; Lan et al., 2009; Roschelle et al., 2010; Chang &amp; Hsu, 2011; Hwang et al., 2011; Laru et al., 2012; Lin et al., 2013; Sung et al., 2013; Song, 2014</td>
<td>10</td>
<td>16%</td>
</tr>
<tr>
<td>Student satisfaction/attitude/perception</td>
<td>Wei &amp; Chen, 2006; Zurita &amp; Nussbaum, 2007; Huang et al., 2008; Huang et al., 2009; El-Bishouty et al., 2010; Chang &amp; Hsu, 2011; Echeverría et al., 2011; Hwang et al., 2011; Wong et al., 2011; Lin et al., 2012</td>
<td>10</td>
<td>16%</td>
</tr>
</tbody>
</table>
Metacognitive strategies
Lim & Wang, 2005; White, 2006; Cortez et al., 2009; Lan et al., 2009; Liu et al., 2009; Nussbaum et al. 2009; Boticki et al., 2011

Process of collaborative investigations
Colella, 2000; Rogers & Price, 2008; So et al., 2009; Ryu & Parsons, 2012; So et al., 2012; Song, 2014

Perception of learning skills (problem solving/inquiry skills, collaborative skills)
Sánchez & Olivares, 2011; Song, 2014

Participation in collaborative activities
Wei & Chen, 2006; Liu et al, 2009; El-Bishouty et al., 2010

Self-efficacy and the local culture identity
Sung et al., 2013

Affordances and limitations of collaborative learning system/tool
Dunleavy et al., 2009

Methods adopted in mCSCL research

The methods utilized in mCSCL research were coded (Gress et al., 2010) and classified into 7 types for the measurement of the effectiveness of mCSCL. They are summarized in Table 4.

<table>
<thead>
<tr>
<th>Methods</th>
<th>Instruments/techniques</th>
<th>No. &amp; %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Self-report</td>
<td>Questionnaires, surveys, summative project reports</td>
<td>16 (18%)</td>
</tr>
<tr>
<td>Interviews</td>
<td>Discussions between researchers, teachers and students</td>
<td>11 (12%)</td>
</tr>
<tr>
<td>Observations</td>
<td>All methods of visually examining and documenting actions and utterances of participants, either directly or by videotape recording</td>
<td>13 (15%)</td>
</tr>
<tr>
<td>Process data</td>
<td>Estimates of time, frequency, and sequence, as well as tracing data which examined participants’ actions via the computer during the collaborative tasks</td>
<td>14 (16%)</td>
</tr>
<tr>
<td>Discussions &amp; dialogues</td>
<td>Engaged purposeful conversation and/or verbal expressions coded as either asynchronous or synchronous communication.</td>
<td>6 (7%)</td>
</tr>
<tr>
<td>Performance &amp; products</td>
<td>All output produced by participants’ collaborative activities</td>
<td>24 (27%)</td>
</tr>
<tr>
<td>Feedback</td>
<td>Feedback from participants, teachers, researchers</td>
<td>4 (5%)</td>
</tr>
</tbody>
</table>

Some of the studies employed more than one type of method (instruments/techniques) ranging to up to six types. Percentages are shown in Figure 3.

Figure 3. Number of types of methods adopted in the 35 studies
Research Question (2): When are the methods conducted?

The timing of measurement was classified into 3 types in the 35 studies: before, during and after the mCSCL practices. The results show that 10 studies (18%) did the assessment before the mCSCL practices, and 23 studies (42%) did the assessment during the mCSCL practices, and 22 studies (40%) did the assessment after the mCSCL practices.

Further, an investigation was carried out to discern the patterns of assessment at different timings with varied methods as shown in Table 5. Table 5 displays that the assessment before the mCSCL practices emphasises (a) prior knowledge/skills; (b) student satisfaction/attitude/ perception towards learning system/tool, and (c) baseline information about self-efficacy and the local culture identity.

The assessment during the mCSCL practices focused on (a) collaborative behaviors/ patterns, (b) metacognitive strategies; (c) process of collaborative investigations; (d) participation in collaborative activities; and (e) affordances and limitations of collaborative learning system/tool.

Finally, the assessment after the mCSCL practices centered on (a) learning performance; (b) student satisfaction/attitude/ perception towards learning system/tool; (c) perception of learning skills (problem solving/ inquiry skills, collaborative skills; (d) metacognitive strategies, and (e) self-efficacy and the local culture identity.

<table>
<thead>
<tr>
<th>Timing</th>
<th>Measures</th>
<th>Studies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before</td>
<td>prior knowledge/skills</td>
<td>White, 2006; Zurita &amp; Nussbaum, 2007; Lan et al., 2009; Chang &amp; Hsu, 2011; Laru et al., 2012; Sung et al., 2013; Song, 2014</td>
</tr>
<tr>
<td></td>
<td>Student satisfaction/attitude/ perception towards Learning system/tool</td>
<td>Chang &amp; Hsu, 2011; Hwang et al., 2011, Lin et al., 2013</td>
</tr>
<tr>
<td></td>
<td>baseline information about self-efficacy and the local culture identity</td>
<td>Sung et al., 2013</td>
</tr>
<tr>
<td>During</td>
<td>collaborative behaviors/ patterns</td>
<td>Zurita &amp; Nussbaum, 2004; Lan et al., 2007; Lan et al., 2009; Capponi et al., 2010; Wong et al., 2011; Timmis, 2012; Wong et al., 2012; Lin et al., 2013</td>
</tr>
<tr>
<td></td>
<td>metacognitive strategies</td>
<td>Lim &amp; Wang, 2005; White, 2006; Cortez et al., 2009; Nussbaum et al. 2009; Boticki et al., 2011; Lan et al., 2012</td>
</tr>
<tr>
<td></td>
<td>process of collaborative investigations</td>
<td>Colella, 2000, Rogers &amp; Price, 2008; So et al., 2009; Ryu &amp; Parsons, 2012; Song, 2014</td>
</tr>
<tr>
<td></td>
<td>participation in collaborative activities</td>
<td>Wei &amp; Chen, 2006; Liu et al, 2009; El-Bishouty et al., 2010</td>
</tr>
<tr>
<td></td>
<td>affordances and limitations of collaborative learning system/tool</td>
<td>Dunleavy et al., 2009</td>
</tr>
<tr>
<td>After</td>
<td>Learning performance</td>
<td>Cortez et al., 2005; Zurita &amp; Nussbaum, 2007; Rogers &amp; Price, 2008; Roschelle et al, 2010; Chang &amp; Hsu, 2011; Hwang et al., 2011; Laru et al., 2012; Ryu &amp; Parsons, 2012; Lin et al., 2013; Sung et al., 2013; Song, 2014</td>
</tr>
<tr>
<td></td>
<td>Student satisfaction/attitude/ perception towards Learning system/tool</td>
<td>El-Bishouty et al., 2010; Huang et al., 2008; Huang et al., 2009; Echeverría et al., 2011; Lan et al., 2012; Wong et al., 2011</td>
</tr>
<tr>
<td></td>
<td>Perception of learning skills (problem solving/ inquiry skills, collaborative skills)</td>
<td>Wei &amp; Chen, 2006; Sánchez &amp; Olivares, 2011; Song, 2014</td>
</tr>
<tr>
<td></td>
<td>Metacognitive strategies</td>
<td>White, 2006; Lan et al., 2009; Liu et al., 2009</td>
</tr>
<tr>
<td></td>
<td>Self-efficacy and the local culture identity</td>
<td>Sung et al., 2013</td>
</tr>
</tbody>
</table>
Some of the studies did the assessment across two or three timings as shown in the above table. 12 studies (36%) assessed students’ learning process and skills during mCSCL practices, 8 studies (22%) assessed students’ learning after the mCSCL practices; while 5 studies (14%) assessed students’ learning in all ranges of timings (before, during and after), 5 studies (14%) did the assessment during and after mCSCL practices, and 5 studies (14%) did the assessment before and after the practices.

How was the assessment conducted among the participants of the 35 studies for mCSCL practices? Two forms of measurement were identified: individual about group and group as a whole. Some of the studies employed both the forms to assess mCSCL practices. About 16 studies (46%) assessed collaboration via group as a whole; 10 studies (28%) assessed collaboration via individual about group and group as a whole studies, and 9 (26%) assessed collaboration via individual about group. None assessed individual about individual.

Research question (3): Have these methods examined mCSCL effectively?

“Premised on the “Analysis framework and analysis process of mCSCL studies” (see Figure 2) developed in this study research question (3) was addressed by (a) grouping the methods adopted in these studies with the timing of the measurement (Gress et al., 2010) resulting from research questions (1) and (2), and (b) contextualizing the 35 eligible studies by referring to the results obtained from the context of studies.

Grouping the methods with timing of measurement

First, the 7 types of methods, which were adopted in the 35 studies 88 times, were grouped together with the timing of the measurement. The frequency of the methods is shown in Table 6.

<table>
<thead>
<tr>
<th>Methods</th>
<th>Measurement timing</th>
<th>Total</th>
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<tbody>
<tr>
<td></td>
<td>Before</td>
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<tr>
<td></td>
<td>n</td>
<td>% n</td>
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<tr>
<td></td>
<td>During</td>
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<tr>
<td></td>
<td>n</td>
<td>% n</td>
</tr>
<tr>
<td></td>
<td>After</td>
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<tr>
<td></td>
<td>n</td>
<td>% n</td>
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</tbody>
</table>

Table 6. Frequency of methods adopted in the 35 mCSCL studies categorized by the measurement of timing

- Self-report
  - Before: 3 (25%), 0 (0%) 0 (0%)
  - During: 0 (0%), 0 (0%) 0 (0%)
  - After: 13 (33%), 15 (15%) 16 (18%)

- Interviews
  - Before: 0 (0%)
  - During: 0 (0%)
  - After: 11 (28%), 12 (12%) 11 (12%)

- Observations
  - Before: 0 (0%)
  - During: 11 (28%)
  - After: 11 (12%)

- Process data
  - Before: 0 (0%)
  - During: 14 (39%)
  - After: 14 (16%)

- Discussions and dialogues
  - Before: 6 (17%)
  - During: 14 (39%)
  - After: 14 (16%)

- Performance and products
  - Before: 9 (75%), 10 (10%)
  - During: 13 (36%), 15 (15%) 15 (15%)
  - After: 13 (15%), 17 (17%) 24 (27%)

- Feedback
  - Before: 0 (0%)
  - During: 3 (8%)
  - After: 1 (2%)

Total
- Before: 12 (100%), 13 (13%)
- During: 36 (100%), 42 (42%)
- After: 40 (100%), 45 (45%)

It is noted from Table 6 that only 12 methods (13% of the total methods) were concerned with assessment before the mCSCL practices. The measures mainly concentrated on using performance and products (10%) to measure prior domain knowledge and collaborative skills; while 3% of the total methods used self-report (e.g., questionnaires) to measure student satisfaction/attitude/perception towards learning system/tool identity (e.g., Chang & Hsu, 2011; Hwang et al., 2011), and baseline information about self-efficacy and the local culture (Sung et al., 2013).

During the mCSCL practices, it was found that 36 methods (42% of the total methods) were used, among which, 13 methods (15%) used observation, 14 methods (16%) used process data followed by 6 methods (7%) of discussions and dialogues and 3 methods (4%) of feedback. These methods were used to assess collaborative behaviors/patterns, metacognitive strategies, process of collaborative investigations, participation in collaborative activities and affordances and limitations of collaborative learning system/tool.

After the mCSCL practices, it was found that 40 methods (45% of the total methods) were used, among which, 13 methods (15%) adopted self-report and 11 methods (12%) used interviews, 15 methods (17%) used performance and
products and 1 method (1%) used feedback to assess: learning performance, student satisfaction/attitude/ perception towards learning system/tool, perception of learning skills such as problem solving/inquiry skills, collaborative skills, metacognitive strategies, and self-efficacy and the local culture identity.

**Contextualizing the 35 eligible studies**

This section presents the results from contextualizing and comparing 35 eligible studies in order discern methodological patterns.

It was observed that a fairly low number of methods (13%) were conducted before the mCSCL practices and a comparatively high number of methods (45%) were administered after the mCSCL practices although 44% of the 35 studies adopted experimental designs. In addition, it was found that the majority of the 35 studies (21 studies, 60%) had sample sizes ranging from 10-50, and 2 studies (5%) only had sample sizes smaller than 10. Thus, the significance of the results from assessment before and after mCSCL practices is challenged.

Next, it is noted that although 42% of the total methods were employed during mCSCL practices, the intervention duration tended to be too short, ranging from 1 day to 4 weeks among 48% of the total 35 studies although all the concerned studies reported positive results. This poses a challenge against the sustainability of the collaborative process in these studies in the long run. In addition, many of the studies lacked a clear coding framework and chose only short episodes of the process data. Thus, the measures are ambiguous.

Moreover, based on the publication years, the context of studies and methodological approaches were compared across the 35 studies. Out of the 17 studies published during the years 2000-2009, 71% adopted PDAs/Palms or mobile devices with wireless connection (including intranet connection), and the rest used Tablet PCs, smartphones or other wearable devices with wireless connection; while out of the 18 studies published during 2010-2014, 56% adopted smartphones or iPads, and the rest used PDAs or mobile phones. With the evolution of mobile devices, the methodological approaches in the studies also evolved: (a) before 2000-2009, the context of the studies was either in-class or out-of-class planned activities; from 2010, the context of some studies included both in-class and out-of-class planned activities (e.g., Hwang et al., 2011; Song, 2014); ((b) from 2010, more and more studies focused on examining contextualized just-in-time content creation and meaning making in learners’ collaborative learning experiences in real life encounters (e.g., Ryu & Parsons, 2012; So et al., 2012; Song, 2014; Wong et al., 2012), and (c) from 2010, design-based research (Collins, Joseph, & Bielaczyc, 2004) was on the rise (e.g., Roschelle et al., 2010; Wong et al., 2012), which attempts to combine theory-driven design with empirical analyses of practices in real settings. It is noted that design-based research is not unique to mCSCL but was developed and practiced by a group of learning scientists in early 21st century. Despite these changes in mCSCL practices, it is also to be noted that existing methods (e.g., self-report, interview, observation) and measures (learning performance, collaborative behaviors/patterns) were widely employed across these studies.

**Research question (4): What issues do the methodological approaches have in existing mCSCL studies?**

This research question is addressed based on the results from the first 3 research questions as well as the analysis framework (see Figure 2). Issues of the methodological approaches are pinpointed and summarized in the following seven aspects.

**Lack of methods before mCSCL practices**

The results of the review study revealed that only a small number of studies conducted measurement before the mCSCL activity, and these methods before mCSCL practices focus on using self-report to measure prior knowledge or skills, and students’ perception/attitude towards the collaborative learning system or tool. Other methods such as interviews and focus group discussions were not tapped into for baseline information in the 35 studies. The form of assessment was restricted to individual about group.


*Lack of methods of examining mCSCL processes*

Although less than half of the 35 studies employed measurement *during* the mCSCL activity and assessed collaboration via the group as whole, the types of methods were limited largely to interview, observation, process data and discussion and dialogues. The descriptive approach, if used properly for fine-grained analysis, can provide rich pictures of interactions (Stahl, 2006). However, in many cases, only short episodes of collaborative discussion data were selected for the analysis without clear coding schemes, the process of collaboration was not clearly revealed, and sometimes the methods adopted were vague. This may be due to difficulties in capturing mobile learners’ learning trails anywhere, anytime (Song, 2014), and a lack of learning analytics tools to analyze, visualize and communicate the research findings (Siemens & Long, 2011). In addition, few studies adopted multiple methods to examine and triangulate the results of interactions.

*Domination of assessment results after mCSCL practices*

Almost half of the measurements were administered *after* the mCSCL activity. This implies that the results of the measurement could show only students’ individual products or outcomes within groups instead of providing a picture of the overall structure of flow of the group communication, or how individuals contribute to this process (Hmelo-Silver & Bromme, 2007). Such issues exist in the CSCL research literature, but appear to be more noticeable in mCSCL studies due to the constant changing of learning contexts (Looi et al., 2012). Therefore, students were not able to witness their collaborative learning process, identify problems and be active agents to improve their learning.

*Short interventions and small sample sizes*

Almost half of the studies did the measurement *after* the mCSCL practices and reported the improvement of collaborative performance and positive attitudes towards the collaboration. However, it is observed that many of these studies had short interventions with a small sample size. This triggers a doubt as to whether the positive results reported *after* mCSCL practices were due to the “novelty effect” (Thornton & Houser, 2005, p. 224), or the “Hawthorne effect” (Swan et al., 2005, p. 110); and whether the results of the measurement were significant with such a small sample size.

*Lack of replication and sustainability of mCSCL research*

Because many of these mCSCL studies tended to fall into the category of trials and pilots (Looi et al., 2012) without fine-grained details for measurement and without multiple types of methods, it is hard for these studies to be replicated in future mCSCL research, hence, it is even harder to be sustained.

*Domination of in-class planned learning environments in the research design*

In all the 35 eligible studies, 85% of them were conducted in “planned learning in-class” (65%) or “planned learning out-of-class” (20%); and 63% of all studies used the mobile devices as a collaborative learning system or tool in the collaborative process. This suggests that students’ learning processes were driven by the learning system or tool use in learning environments designed by the teacher rather than in authentic learning environments where students have the control of their own learning (Song, 2007).

*Lack of the “mobility” nature of mCSCL practices*

The most noticeable phenomenon found in this review is that in all the reviewed studies, the “mobility” nature of mCSCL practices was not adequately addressed from the lens of seamless learning (Wong & Looi, 2011). According to Looi et al. (2012), mCSCL does not simply mean “mobile + CSCL,” it indicates the changing practices that “mobile” technologies have initiated via continually re-constructed contexts and the instantaneous nature of
collaboration (Patten, Sánchez, & Tangney, 2006). This, in turn, implies that opportunities for student immediate mCSCL would make more knowledge generation possible, and further encourage active participation in the learning activity (Ryu & Parsons, 2012). However, the findings of this review show that in many of the eligible studies, the context of student learning has tended to be confined to “planned learning in-class” such as fixed physical classrooms, or “planned learning out-of-class” such as field trip types of studies (e.g., So et al., 2012). Few studies have attempted to measure collaborative learning across individual and social, physical and virtual and formal and informal learning simultaneously. The dynamic nature of mCSCL practices across different spaces remains scant although such practices have drawn researchers’ attention, and work has begun towards such endeavors (e.g., Arrigo et al., 2013; Song, 2014; Wong et al., 2012). In addition, in the majority of the studies, the mobile devices were provided by schools or institutions, which hinders students’ own exploration of the device to support their learning and makes students feel lack of ownership of their learning (Song, 2014).

Discussions

Compared to the findings and commentary from CSCL research literature (e.g., Hmelo-Silver & Bromme, 2007; Gress et al., 2010) and other related mobile educational application literature (e.g., Arrigo et al., 2013; Hsu, Y.-C., & Ching, 2013; Looi et al., 2012; Wong & Looi, 2011), findings from this mCSCL review show three distinctive features. First, more and more recent mCSCL studies attempted to capture contextualized just-in-time artifacts created by mobile devices and examine collaborative learning in authentic learning environments (e.g., So et al., 2012; Ryu & Parsons, 2012; Wong et al., 2012). Secondly, although existing issues of measurement in CSCL studies have also been identified in mCSCL practices, it is noted that these issues appear even more evident in mCSCL practices, such as a lack of replication of the practices across different contexts and collaborative models, and a lack of instruments for examining the collaborative process and the like. For example, although 63% of the studies have made use of the mobile devices as collaborative learning systems/tools, they have been used in a variety of ways for different purposes in different learning contexts ranging from using the system/tool as a medium for group collaborative discussion between students in groups to change the classroom dynamic (e.g., Cortez et al., 2005; Zurita & Nussbaum, 2007), as a way to develop student reading skills in second language (L2) learning (Lan et al., 2009), to being a model of personalized collaborative ubiquitous learning to support students doing tasks and activities (El-Bishouty et al., 2010). In addition, the measures are quite varied (10 different measures in the 35 studies). Thus, it is harder to replicate the practices and more challenging to capture and analyze the collaborative processes. Secondly, the measurement timing in mCSCL practices focuses on measurement after the collaborative activities (45% of the studies), the sample size tends to be small (60% of studies have a sample size from 10-50 participants) with a short intervention (about half of the studies conducted their intervention from 1 to 4 weeks), and many studies tend to be small-scale trials (Looi et al., 2012). Thus, despite that the research findings of mCSCL studies show favorable results, the effectiveness of measurement needs further justifications. Last but not least, although planned learning practices in both in- and out-of-class and design-based research are on the rise to foster learners’ collaborative learning, new endeavors are still scant to address methodological issues in mCSCL practices. Thus, the review study brings to light the following potential directions for further mCSCL research:

- Focus on using multiple methods across different measurement timings (before, during and after the mCSCL activity) in the design of mCSCL research (Gress et al., 2010; Hmelo-Silver & Bromme, 2007);
- Provide clear coding framework and measures to assess the process of collaboration in fine-grained detail (Hmelo-Silver & Bromme, 2007; Stahl, 2006);
- Design research with longer interventions and larger sample sizes to make the research results more robust;
- Adopt a method to collect and analyze big data (e.g., learning analytics) across different contexts to make the students visualize their collaborative learning process and guide them in the learning process with the ultimate goal of optimizing their collaborative knowledge construction and developing collaborative skills (Ogata et al., 2014; in the meantime provide opportunities for teachers to identify problems for pedagogical decision making (Long & Siemens, 2011);
• Design research in which students’ collaboration distributes in different spaces (e.g., formal and informal, and virtual and physical learning spaces) using their own mobile devices with existing applications rather than using designed learning systems or tools; and

• Lay emphasis on investigating viable and novel methodological approaches that address how to capture students’ collaborative process and outcomes in the mobile, reconstructed contexts. For example, Hakkarainen (2009) proposes using mobile devices for contextually and repeatedly sampling students’ knowledge practices in their natural context to examine students’ intellectual and emotional processes at personal and collective levels related to their triological (object-related) knowledge-advancement efforts. By doing so, important pedagogical implications can be uncovered in mCSCL practices.

• Design mCSCL activities that span across different spaces to bridge formal and informal learning with social network platforms to develop students’ lifelong learning and collaborative skills.

Conclusions

This study conducted a systematic review of the methodological approaches of 35 eligible mCSCL studies. An analysis framework was developed to address four research questions regarding what methods have been adopted, when the measurements were administered, whether the methods are effective and what methodological issues are discovered. The research finding shows seven methods were employed to evaluate the 10 types of measures, and the timing of measurement spread across before, during and after mCSCL practices. By grouping the methods with the timing of measurement premised on the analysis framework and contextualizing the reviewed studies, it was found that in many cases, the methods might not be able to measure what the studies intended to measure effectively. Seven issues of methodological approaches were pinpointed and discussed. It should be noted that the findings of this review are limited due to the relatively small number of examples of studies analyzed. A further attempt is envisaged to critically review such issues with more detailed description and analysis in mCSCL studies.

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References


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