Liu, C.-C. et al. (Eds.) (2014). Proceedings of the 22nd International Conference on Computers in Education. Japan: Asia-Pacific Society for Computers in Education

A systematic review of assessment methods in mobile computer-supported collaborative learning (mCSCL)

Yanjie SONG
Department of Mathematics and Information Technology, Hong Kong Institute of Education, Hong Kong, PRC
ysong@ied.edu.hk

Abstract: This study aims to investigate (1) assessment measures utilized in Computer-Supported Collaborative Learning (mCSCL) research; (2) whether these assessment measures have examined the effectiveness of mCSCL that the studies intend to assess; and (3) when the assessment measures are conducted in mCSCL research in an attempt to bring to light potential methods that are conducive to examining effectiveness of mCSCL practices and sustain the practices, and identify methodological issuesin mCSCL to be addressed in future research. The research findings show a variety of methodological issues that need to be addressed. Discussions are made in comparison with the findings in CSCL research and other studies leveraged by mobile technologies. Potential directions to investigate the effectiveness of mCSCL practices are proposed.

Keywords: mCSCL, assessment measures, objects of assessment, methodological approach

1. Introduction

Computer-supported collaborative learning (CSCL) 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) 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 of "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 the changing practices partly due to unique technology characteristic of "mobility" and the dynamically re-constructed context for interaction and learning (Looi, Wong, & Song, 2012).

Various tools and systems have been increasingly developed on, or integrated into, the mobile devices for mCSCL. These activities have been carried out across different spaces physically, socially and virtually. Despite that a number of studies have reported the benefits gained from the implementation of the mobile tools or systems for mCSCL, little impact has been observed on actual school practices outside the context of research investigations (Roschelle et al., 2010). To uncover the "black box" of mCSCL research, this study aims to investigate current methodology approaches to assessing learning processes and outcomes in mCSCL through a systematic review of the literature. The research questions are:

(1) What assessment measures are utilized in mCSCL research?
(2) When are the assessment measures conducted?
(3) Have these assessment measures examined the effectiveness of mCSCL that the studies intend to assess? (data analysis)
(4) What issues do the methodological approaches have in existing mCSCL studies?

This study attempts to bring to light potential methods that are conducive to examining effectiveness of mCSCL practices and sustain the practices, and identify methodological design issues in mCSCL to be addressed in future research.

The organization of the paper is as follows. First it describes the method in doing the literature review, followed by the presentation of the results of the review. Then, discussions are made based on the review results. Finally, future research in mCSCL is explored.

2. Methods

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 these studies (Coffield et al., 2004; Wong & Looi, 2011). In general, the first phase of a systematic review is a thorough search of the relevant literature, followed by a check of criteria in selecting articles that meet the review purposes. The second phase is the review process, and the third phase is to write the report of the review.

2.1 Selection criteria

To address the research questions, a set of criteria were worked out in selecting articles that met our 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 mobile devices that can be held and operated using one hand such as PDAs, Smartphones, iPad, and mobile phones; and (e) studies published in refereed journals. Thus, in this review, studies that have used laptop computers to support collaboration are excluded due to "mobility" concerns. In addition, studies that are concerned mainly with conceptual frameworks, literature review, and technical infrastructures are beyond the focus of this review, and are excluded.

2.2 Identification of eligible mCSCL studies

The literature search and review underwent three stages. First, an extensive literature search was conducted in 3 major refereed academic journals related to technology-enhanced teaching and learning research, using the key words "mCSCL", or "mobile computer-supported collaborative learning", and "mobile" and "collaborative learning".

As of February 2014, the search of the previous publications in these journals yielded 122 results, among which, 31 articles met the criteria. The second round of search was conducted in Google Scholar using the same key word search as the literature search in referred journals. The first 10 ten pages of search results of each key word combinations were viewed, from which 3 more articles were added to the pool. Finally, the third round of search used 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 review and analysis.

2.3 Analysis of mCSCL studies

This analysis is illuminated by the review study on examining measurement and assessment in CSCL (Gress, Fior, Hadwin, & Winne, 2010). According to Hmelo-Silver and Bromme (2007), assessment and methodological approaches are dependent on the theoretical framework being used and research questions being asked. Assessment in CSCL can take one of the three forms: assessing the individual about the individual, assessing the individual about the group, and assessing the group as a whole (Gress et al., 2010; Hmelo-Silver & Bromme, 2007). Assessment measuresin CSCL includes observing, capturing and summarising both individual and group behaviours, 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). Stahl (2002) posits that in CSCL, ''for collaborative learning processes to be visible to researchers, the participant interactions must be available for careful study and

the researchers must be capable of interpreting them appropriately'' (p. 178). Does it apply to mCSCL practices? Due to the limited screen size, and mobility nature of mobile devices, collaborative learning may happen in constantly changing contexts. Thus, to make mobile collaborative learning process visible is an even more demanding task. To understand mCSCL practices, we need to examine holistically and "re-construct" (Looi et al., 2012) learning scenarios occurring in different contexts. To demonstrate how mCSCL environment and tools benefit learning, it is essential to focus on methodological approaches in relation to assessment measures, object of assessment and analysis (Gress et al., 2010; Hmelo-Silver & Bromme, 2007).

Based on Gress et al (2010)'s coding scheme of research and design in CSCL, to address the four research questions, an analysis framework was developed for the purposes of reviewing and analysing mCSCL research. The framework consists of five elements: Context of studies, research design and foci, assessment measures, objects of assessment, and timing of assessment.

(a) Contexts of studies: include participants, sample size, duration of intervention, domain areas, adopted mobile technology/tools, and settings (in-class, planned/emerging; out-of-class, planned/emerging; in-and out-of-class, mixed).

(b) Research design and foci: 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) Assessment measures: refer to all the instruments such as questionnaires, surveys, discourse analysis, content analysis, and artifact analysis used in mCSCL and methods used in the articles such as interviews, observations, discussions, and process data.

(d) Objects of assessment: refer to the things that are assessed in the studies. Based on the research focus, objects of assessment were further identified. For example, the object of assessment in Laru et al. (2012) was *co-construction of arguments.*

(e) Timing of the measurement (before, during or/and after): refer to the assessment timing (before, during, or after mCSCL practices) in the studies (Gress et al., 2010) (e.g., assessing students' performance after collaboration in Laru et al., 2012). In addition, forms of assessment (assessing the individual about the individual, assessing the individual about the group, 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 was conducted across the 35 articles. 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 1.

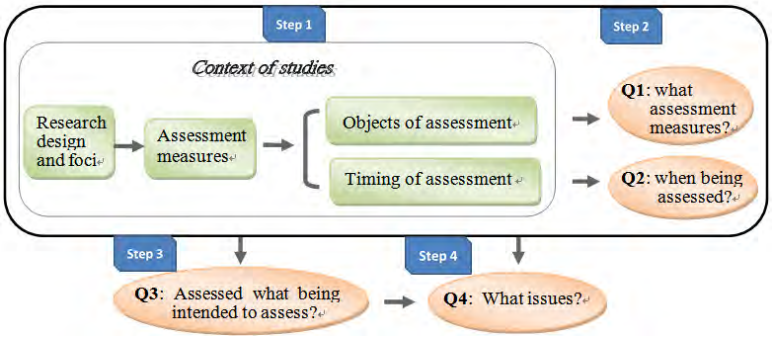

Figure 1. Analysis framework and analysis process of the 35 mCSCL studies

In the first step, all the individual articles were coded based on the 5 elements of the analysis framework. A preliminary table was worked out. Then a further categorization of the articles was made to securitize the characteristics of each element in the framework: (a) the context of studies were categorized into participants (primary, secondary, tertiary education or others), sample sizes (<10, 10–50, 51–100, and >100), duration of 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 foci (e.g., methodology and the aims/objectives of studies); (c) objects of assessment; (d) Assessment instruments, and / or methods including and forms of assessment; and finally (e) timing of the assessment.

The second step focused on identifying common themes of mCSCL practices and effects in five dimensions across 35 articles to address the first two research questions (Q1: what assessment measures? And Q2: when being assessed?). 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: Assessed what being intended to assess?). Finally the fourth step, based on the previous three steps' work, addressed the fourth research question (Q4: What issues?).

3. Results

3.1 Context of studies

Before showing the results of the research questions, the context of the 35 studies are presented to provide a general picture of mCSCL practices. The context of study influenced the measurement of collaborative practices (Hmelo-Silver & Bromme, 2007). The context of the 35 studies was categoriesed in terms of the following elements:

(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%) of them had the sample sizes ranging from 10-50, and 2 (5%) of them 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 the research intervention ranging from 1 to 4 weeks. Ten studies (28%) had 1 to 5 days' research interventions, which accounts to the largest percentage of among all studies; and 2 studies (6%) did not report how long the intervention was involved.

(d) Domain areas: The domain areas of 12 (29%) studies were concerned with 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 devices: There were 13 studies (36%) chose smartphones as the mobile devices to support students' collaborative study, followed by the mobile devices of PDAs (34%), mobile phones (14%), Tablet including iPad (8%), and others (8%). In the 35 studies, the mobile devices were adopted for different uses. Most of the studies (63%) used the mobile devices as a collaborative learning system, 9 studies (26%) used the mobile device as games or an argument reality (AR) tool, and 4 studies (8%) employed the mobile devices as a scaffolding tool, and 1 study (3%) made use of the mobile devices as an annotation tool. (f) Settings: It is found that the majority of studies (65%) carried out the research in "in-class planned learning environments", followed by "out-of-class planned environments" (20%) and "in-and out-of-class mixed environments" (15%). No research is identified to be carried out in unplanned, "emerging learning environments".

3.2 Research Question (1): What assessment measures are utilized in mCSCL research?

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

3.2.1 Research design and foci

The research foci of all the 35 studies were classified into five categories: (a) improve collaborative activity/process/learning using CSCL systems (12 studies, 34%); (b) evaluate the effectiveness of learning systems/tools (10 studies, 29%); (c) improving collaborative learning strategies/approaches (8 studies, 23%); (d) exploring the educational potential of learning systems/tools (4 studies,11%); and (e) adopting the methodology of discovering social action 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 cased studies, 5 (14%) studies doing learning system evaluation, and four studies (11%) using design-based research approach.

3.2.2 Assessment measures adopted in mCSCL research

The assessment measures (e.g., instruments and /or methods) utilised in mCSCL research were coded (Gress et al., 2010) and classified into 7 types, which are summarised in Table 1.

Table 1: Methods, instruments/techniques and distribution among the 35 studies

Methods	Instruments/techniques	
Self-report	Questionnaires, surveys, summative project reports	16 (18%)
Interviews	Discussions between researchers, teachers and students	11 (12%)
Observations	All methods of visually examining and documenting actions and utterances of participants, either directly or by videotape recording	13 (15%)
Process data	Estimates of time, frequency, and sequence, as well as trace data which examined participants' actions via the computer during the collaborative tasks	14 (16%)
Discussions & dialogues	Engaged purposeful conversation and/or verbal expressions coded as either asynchronous or synchronous communication.	6 (7 %)
Performance &products	All output produced by participants' collaborative activities	24 (27%)
Feedback	Feedback from participants, teachers, researchers	4 (5%)

Some of the studies employed more than one type of assessment measures ranging from one type to six types, in which 31% adopted one type and two types of assessment measures respectively.

3.2.3 Objects of assessment

Eleven types of objects that were assessed were identified. They are: learning performance (18%); collaborative behaviors/patterns (18%); prior knowledge/skills (16%); student satisfaction/attitude/ perception towards Learning system/tool (16%); metacognitive strategies (13%); 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 objects to achieve their research aims.

3.3 Research Question (2): When are the assessment measures conducted?

The timing of assessment 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 22 studies (40%) did the assessment *during* the mCSCL practices, and 22 studies (40%) did the assessment *after* the mCSCL practices, and 1 studies (2%)'s assessment timing was not clear. Further, an investigation was carried out to discern the patterns of assessment at different stages.

It was found that the assessment *before* the mCSCL practices emphasises on (1) prior knowledge/skills (e.g., White, 2006; Zurita & Nussbaum, 2007; Lan et al., 2009; Chang & Hsu, 2011; Laru et al., 2012; Sung et al., 2013; Song, 2014); (b) Student satisfaction/attitude/ perception towards Learning system/tool (Chang & Hsu, 2011; Hwang et al., 2011, Lin et al., 2013), and (c) baseline information about self-efficacy and the local culture identity (Sung et al., 2013).

The assessment *during* the mCSCL practices focused on (a) collaborative behaviors/ patterns (Zurita & Nussbaum, 2004; Lan et al., 2007; Lan et al., 2009; Capponi et al., 2010; Wong et al., 2011; Timmis, 2012; Lin et al., 2013), (b) metacognitive strategies (Lim & Wang, 2005; White, 2006; Cortez et al., 2009; Nussbaum et al. 2009; Boticki et al., 2011; Lan et al., 2012); (c) process of collaborative investigations (Colella, 2000, Rogers & Price, 2008; So et al., 2009; Ryu & Parsons, 2012; Song, 2014); (d) participation in collaborative activities (Wei & Chen, 2006; Liu et al, 2009; El-Bishouty et al., 2010); and (e) affordances and limitations of collaborative learning system/tool (Dunleavy et al., 2009).

Finally, the assessment *after* the mCSCL practices centred on (a) Learning performance (Cortez et al., 2005; Zurita & Nussbaum, 2007; Rogers & Price, 2008; Roschelle et al, 2010; Chang & Hsu, 2011; Hwang et al., 2011; Laru et al., 2012; Ryu & Parsons, 2012; Lin et al., 2013; Sung et al., 2013; Song, 2014); (b) Student satisfaction/attitude/ perception towards Learning system/tool (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) (c) Perception of learning skills (problem solving/ inquiry skills, collaborative skills (Wei & Chen, 2006; Sánchez & Olivares, 2011; Song, 2014); (d) Metacognitive strategies (White, 2006; Lan et al., 2009; Liu et al, 2009) and (e) Self-efficacy and the local culture identity (Sung et al., 2013).

Some of the studies did the assessment across two or three timings, 12 studies (33%) 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 range of timing (before, duration and after), 5 studies (14%) did the assessment during and after mCSCL practices, 5 studies (14%) did the assessment before and after the practices, and 1 studies (3%) did not present the assessment with adequate evidence.

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 of the forms to assess mCSCL practices (see Figure 8). About 15 studies (43%) 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, and one study (3%) did not show clearly how collaboration was assessed.

3.4 Research question (3): Have these assessment measures examined the effectiveness of mCSCL that the studies have intended to assess?

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 assessment measures adopted in these studies with the timing of the assessment (Gress et al., 2010) resulted from research questions (1) and (2), and (b) contextualizing the 35 eligible studies by referring to the results obtained from context of studies.

3.4.1 Grouping the measures with timing of measurement

First, the 7 types of assessment measures that were adopted in 35 studies for 88 times were grouped together with the timing of the measurement. The frequency of measures is shown in Table 2.

Table 2: Frequency of assessment measures adopted in the 35 mCSCL studies categorized by the measurement of timing

Measure type	Measurement timing									Total	
	Before			During			After				
	n	% n*	% N**	n	% n	% N	n	% n	% N	n	% N
Self report	3	25%	3%	0	0	0	13	33%	15%	16	18%
Interviews	0	0		0			11	28%	12%	11	12%
Observations				13	36%	15%				13	15%
Process data				14	39%	16%				14	16%
Discussions & dialogues				6	17%	7%				6	7%
Performance and products	9	75%	10%				15	37%	17%	24	27%
Feedback				3	8%	4%	1	2%	1%	4	5%
Total n	12	100 %	13%	36	100 %	42%	40	100 %	45%	88	100 %

*% n = Percentage of assessment measures in each type of timings (before, during, and after)
**% N = Percentage of assessment measures among all types of timings (before, during, and after)

Before mCSCL practices, it is noted from Table 2 that only 12 assessment measures (13% of the total measures) were adopted before the mCSCL practices. The measures mainly concentrated on

using *performance and products* (10%) to assess prior domain knowledge and collaborative skills; while 3% of the studies used *self report* to assess student satisfaction/attitude/perception towards learning system/tool and baseline information about self-efficacy and the local culture identity.

During the mCSCL practices, it is found that 36 assessment measures (42% of the total measures) were used, among which, 13 measures (15%) used observation, 14 measures (16%) used process data followed by 6 measures (7%) of discussions and dialogues and 3 measures (4%) of feedback. These measures 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 is observed that 40 assessment measures (45% of the total measures) were used, among which, 13 measures (15%) adopted self-report and 11 measures (12%) used interviews, 15 measures (17%) used performance and products and 1 measure (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.

3.4.2 Contextualizing the 35 eligible studies

The assessment measures of all the 35 studies were examined in their own context of studies as well as the timing and form of the assessment. It is observed that there was a fairly low number of assessment measures (13%) that were conducted before the mCSCL practices and a comparatively high number of measures (45%) that were administered after the mCSCL practices although 44% of the 35 studies adopted experimental designs. This indicates that the majority of the experimental studies only tested students' collaboration after their mCSCL practices. In addition, the measures adopted before mCSCL practices focused mainly on performance or collaborative skills' indicators. No studies assessed students' readiness to collaborate which was considered important for fruitful communication (e.g., Gress et al., 2010). On the other hand, it was found that the majority of the 35 studies (21 studies, 60%) had the sample sizes ranging from 10-50, and 2 studies (5%) only had the sample sizes smaller than 10. Thus, the significance of the results from assessment before and after mCSCL practices was challenged.

Next, it is noted that although 42% of the total assessment measures 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 challenge against the sustainability of the collaborative process in these studies in the long run. In addition, many of the studies were lack of a clear coding framework and chose only short episode of the process data. Thus, the objects of assessment were ambiguous.

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

This research question was addressed based on the results from the first 3 research questions as well as the analysis framework (see Figure 2). Seven issues of the methodological approaches were pinpointed and summarised in the following seven aspects.

3.5.1 Lack of measures before mCSCL practices

The results of the review study revealed that only a small number of studies conducted assessment before the mCSCL activity, and the assessment measures before mCSCL practices were confined mainly to prior knowledge or skills, and students' perception/attitude towards the collaborative learning system or tool. The form of assessment was restricted to individual about group.

3.5.2 Lack of measures of examining mCSCL processes

Although less than half of the 35 studies conducted assessment during the mCSCL activity and assessed collaboration via group as whole, the types of measures were limited largely to interview, observation, process data and discussion and dialogues. The descriptive approach, if being 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 could not be clearly revealed, and sometimes the objects of measurement were vague. In addition, few studies adopted multiple assessment measures to examine and triangulate the results of interactions.

3.5.3 Domination of results from assessment measures after mCSCL practices

Almost half of the assessment was administered after the mCSCL activity. This implies that the results of the assessment 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). Therefore, students were not able to witness their collaborative learning process, identify problems and be an active agent to improve their learning.

3.5.4 Short interventions and small sample sizes

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

3.5.5 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 assessment and without multiple types of assessment measures, it is hard for these studies to be replicated in future mCSCL research, hence, it is even harder to be sustained.

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

In all the 35 eligible studies, 85% of them were conducted in "in-class planned learning environments" (65%) or "out-of-class planned environments" (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 and evaluated by the learning system or tool use in predefined learning environments.

3.5.7 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 practices does not simply mean "mobile + CSCL", it indicates the changing practices that "mobile" technologies have contributed to in continually re-constructed contexts and instantaneous nature of collaboration (Looi et al., 2012). 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. However, in many of the studies, the context of student studies tended to be confined in fixed physical classrooms. Few studies attempted to assess collaborative learning across individual and social, physical and virtual and formal and informal learning simultaneously. Also, in the majority of the studies, the mobile devices were provided by schools or institutions, which hinder students' own exploration of the device to support their learning and make students feel lack of ownership of their learning (Song, 2014).

4. Conclusion and future research

This study conducted a systematic review of on the methodological approaches among the 35 eligible mCSCL studies, focusing on assessment of mCSCL. An analysis framework was developed to address four research questions regarding what assessment measures have been adopted, when the assessment measurement had been administered, whether the assessment measures are effective and what methodological issues are discovered. The research findings show that seven assessment measures were employed to assess the 11 types of objects of assessment, and the timing of assessment spread across before, during and after mCSCL practices. By grouping the assessment measures with the timing of assessment premised on the analysis framework and contextualizing the reviewed studies, it was found that in many cases, the measures might not be able to assess what the studies have intended to assess effectively. Seven issues of methodological approaches were pinpointed.

The review study brings to light the following potential directions for further mCSCL research:

(a) Focus on using multiple assessment measures across different assessment timings (before, during and after the mCSCL activity) in the design of mCSCL research (Gress et al., 2010; Hmelo-Silver & Bromme, 2007);

(b) Provide clear coding framework and objects of assessment to evaluate the process of collaboration in fine-grained detail (Hmelo-Silver & Bromme, 2007; Stahl et al. 2006);

(c) Design research with longer interventions and larger sample sizes to make the research results more robust;

(d) Adopt the method to deal with big data (e.g., learning analytics) to make the students visualise their collaborative learning process and guide them in the learning process with the ultimate goal of optimising their collaborative knowledge construction and developing collaborative skills; in the meantime provide opportunities for teachers to identify problems for pedagogical decision making (Long & Siemens, 2011);

(e) 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

(f) Lay emphasis on investigating into 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. This is related to the trialogical approach which emphasizes collaborative development of mediating objects or artifacts students' worked on rather than monologues within mind (the acquisition view) or dialogues between minds (the participation view) (Hakkarainen & Paavola, 2009). By doing so, we can understand better how students' construct and advance their knowledge in seamless learning environments, and important pedagogical implications can be uncovered in mCSCL practices.

Acknowledgement

The study was funded by Hong Kong Institute of Education under MIT Small Research Grant *(Ref. MIT/SRG09/13-14)*.

References

Coffield, F., Moseley, D., Hall, E., & Ecclestone, K. (2004). *Learning styles and pedagogy in post-16 learning: A systematic and critical review*. London: Learning and Skills Research Centre, Institute of Education.

Cortez, C., Nussbaum, M., Woywood, G., & Aravena, R. (2009). Learning to collaborate by collaborating: a face-to-face collaborative activity for measuring and learning basics about teamwork. *Journal of Computer Assisted Learning, 25*(2), 126-142.

Gao, F., Luo, T., & Zhang, K. (2012). Tweeting for learning: A critical analysis of research on microblogging in education published in 2008??011. *British Journal of Educational Technology,*

43(5), 783-801.
Gress, C. L. Z., Fior, M., Hadwin, A. F., & Winne, P. H. (2010). Measurement and assessment in computer-supported collaborative learning. *Computers in Human Behavior, 26*(5), 806-814.
Hakkarainen K. (2009). A knowledge-practice perspective on technology-mediated learning International Journal of Computer-Supported Collaborative Learning, 4, 213–231.
Hakkarainen, K., & Paavola, S. (2009). Toward a trialogical approach to learning. In B. Schwarz, T. Dreyfus & R. Hershkowitz (Eds.), Transformation of knowledge through classroom interaction (pp. 65-80).
Hmelo-Silver, C. E., & Bromme, R. (2007). Coding discussions and discussing coding: Research on collaborative learning in computer-supported environments. *Learning and Instruction, 17*(4), 460-464.
Hmelo-Silver, C. E., & Barrows, H. S. (2008). Facilitating collaborative knowledge building. *Cognition and Instruction, 26*(1), 48-94.
Laru, J., Järvelä, S., & Clariana, R. B. (2012). Supporting collaborative inquiry during a biology field trip with mobile peer-to-peer tools for learning: a case study with K-12 learners. *Interactive Learning Environments, 20*(2), 103-117.
Long, P. and Siemens, G. (2011). Penetrating the fog: analytics in learning and education, *EDUCAUSE Review*, *46*(5), 31–40.
Looi, C.-K., Wong, L.-H., & Song, Y. (2012). Discovering mobile Computer Supported Collaborative Learning. In C. Hmelo-Silver, A. O'Donnell, C. Chan & C. Chinn (Eds.), *The International Handbook of Collaborative Learning* (pp. 420-436). New York: Routledge.
Motiwalla, L. F. (2007). Mobile learning: A framework and evaluation. *Computers & Education, 49*(3), 581-596.
Nussbaum, M., Alvarez, C., McFarlane, A., Gomeza, F., Claro, S., & Radovic, D. (2009). Technology as small group face-to-face collaborative scaffolding. *Computers & Education, 52*, 147-153.
Roschelle, J., Rafanan, K., Bhanot, R., Estrella, G., Penuel, B., Nussbaum, M., et al. (2010). Scaffolding group explanation and feedback with handheld technology: impact on students' mathematics learning. *Educational Technology Research and Development, 58*(4), 399-419.
Ryu, H., & Parsons, D. (2012). Risky business or sharing the load? – Social flow in collaborative mobile learning. *Computers & Education, 58*(2), 707-720.
Song, Y. (2014). "Bring Your Own Device (BYOD)" for Seamless Science Inquiry in a Primary School. *Computers & Education, 74*, 50-60.
Stahl, G. (Ed.). (2002). *Computer support for collaborative learning : foundations for a CSCL community*. Mahwah, NJ Lawrence Erlbaum Associates, Inc.
Stahl, G., Koschmann, T., & Suthers, D. D. (2006). Computer-supported collaborative learning: a historical perspective. In R. K. Sawyer (Ed.), *Cambridge handbook of the learning sciences* (pp. 406-427). New York, NY: Cambridge University Press.
Swan, K., van't Hooft, M., Kratcoski, A., & Unger, D. (2005). Uses and effects of mobile computing devices in K-8 classrooms. *Journal of Research on Technology in Education, 38*(1), 99-112.
Thornton, P., & Houser, C. (2005). Using mobile phones in English education in Japan. *Journal of Computer Assisted Learning, 21*(3), 217-228.
Wong, L.-H., Boticki, I., Sun, J., & Looi, C.-K. (2011). Improving the scaffolds of a mobile-assisted Chinese character forming game via a design-based research cycle. *Computers in Human Behavior, 27*(5), 1783-1793.
Wong, L.-H., & Looi, C.-K. (2011). What seams do we remove in mobile-assisted seamless learning? A critical review of the literature. *Computers & Education, 57*, 2364-2381.