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Trends in mobile technology-supported collaborative learning: A systematic review of journal publications from 2007 to 2016

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ABSTRACT

This study reviewed the literature on mobile technology-supported collaborative learning from 2007 to 2016. Several issues, such as the distributions and research methods, learning devices and learning environments, participants, research issues, application domains, grouping methods and collaborative learning strategies, are addressed. In addition, the relationship between the learning strategies and measurement issues are investigated. The review found that the amount of research on mobile collaborative learning increased and the connection between new mobile technology and collaborative learning activities became tighter. College students received the greatest emphasis, but more focus should be put on junior and elementary school students. Few studies were conducted on teachers and adults. In the most recent five years, the research was focused on improving learners' performance in science, especially social science, and in natural scenarios outside of the classroom, but less emphasis was put on developing learners' skills and higher order skills. There was little research focusing on different selection methods of group members and the teaching effects of grouping design. Most research adopted conceptualized collaborative learning strategies. Furthermore, some studies proposed that the collaborative learning activities conducted in mobile learning environments should be designed carefully to guide students to experience more effective collaborative constructivist learning. Based on the findings, in-depth discussion and suggestions for future studies are given.

1. Introduction

Vygotsky (1978) believed that human development depends on one's social experience during childhood, and that such social factors are even more decisive in terms of human development than the traditional cognition theories, including Piaget's cognitive development (Cole, John-Steiner, Scribner, & Souberman, 1978). Having social interaction with peers in the real world can boost students to reflect on their past experiences and thoughts (Hwang, Shi, & Chu, 2011); collaborative learning is important for developing social experiences. Collaborative learning means a teaching method whereby learners get together to learn as a group and help each other to achieve a certain learning target (Panitz, 1999; Slavin, 2014). In practical education and research activities, collaborative learning has received great emphasis from educators and researchers for more than half a century. In the 1970s, collaborative learning was used extensively in all subjects in both in-class and outside-of-class, traditional and non-traditional learning scenarios, and kindergarten and graduate institutes (Johnson, Johnson, & Smith, 2007; Johnson, Johnson, & Stanne, 2000).

More and more researchers have confirmed the effects of collaborative learning (Bertucci, Conte, Johnson, & Johnson, 2010). The main point of collaborative learning is not its effectiveness, but the reasons why and the situations in which it is most effective

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(Slavin, 1996). Slavin (1996) analyzed numerous empirical studies on collaborative learning and found that group targets, individual responsibility, and group interaction are the essential factors of promoting learning achievement. In the grouping numbers in collaborative learning, some researchers have considered that efficiency will increase as the number of people in the group increases; on the other hand, some researchers believe the opposite (Bertucci et al., 2010; Pfister & Oehl, 2009). Neber, Finsterwald, and Urban (2001) analyzed 12 articles on the effects of learning achievement in the homogeneous and heterogeneous grouping methods for gifted students and high-achieving students, and found that there were no consistent opinions on whether homogeneous or heterogeneous grouping led to better performance in terms of improving students' grades. Some researchers have focused on comparing the effects of different collaborative learning strategies (Johnson et al., 2000; Sharan, 1980). From the research, it can be found that collaborative learning is a very complex teaching activity because group targets, interaction modes, grouping numbers, group members, and collaborative learning strategies are all important factors affecting collaborative learning. Therefore, it is necessary to examine the educational functions and values through systems.

In the past decade, through the development and popularity of mobile and wireless technologies, mobile technologies provide a better and wider educational application than conventional information, due to their convenience, connectivity, personalization, and interaction (Sharples, 2000; Terras & Ramsay, 2012). Learning in an environment with mobile technologies has aroused the interest of educators and researchers (Pimmer, Mateescu, & Grohbiel, 2016). In a study on the developmental trend of technology learning from 2000 to 2009, Hsu et al. (2012) found that the number of mobile learning studies rapidly increased in the time period. Based on the mutual definition of mobile learning and ubiquitous learning proposed by Hwang and Tsai (2011), this study defined mobile collaborative learning as a learning approach using mobile devices and wireless technology anytime and anywhere to achieve a certain learning target in a group.

Compared to literature reviews on mobile learning, there are few reviews on mobile collaborative learning. Hsu and Ching (2013) searched for studies on mobile technology-supported mobile learning published during the period 2000 to 2011 and found nine articles. From their analysis, it was found that the main participants in these studies were K-12 students, and three to five people were grouped together. The most frequently used mobile devices were personal digital assistants, and the main issues investigated were learning performance, engagement, participation, and interaction. Song (2014) reviewed the methodological issues in the research domains of Mobile Computer-Supported Collaborative Learning (mCSCL) during the period 2000 to 2014 and found that there was an increasing trend of exploring collaborative learning issues in an authentic learning environment, but there was a lack of instruments to examine the process of collaborative learning.

From the perspective of social constructivism, knowledge is constructed rather than created, and interpersonal interaction within society is critical for the construction of knowledge (Andrews, 2012). In short, mobile-based collaborative learning is essentially a new learning approach to advocate, encourage, and facilitate students' learning with instructors, classmates, and society, both in and outside of the classroom. According to Tsai (2004), technology-based instruction is not only a cognitive or metacognitive tool, but also an epistemological tool for dealing with the nature of knowledge and beliefs. Tsai also hypothesized that learners with different epistemologies might obtain different benefits from internet-based instruction, and internet-based instruction with appropriate guidance plus learners' self-reflection should enable the development of advanced epistemologies, which could conversely facilitate the effectiveness of internet-based instruction.

In sum, those previous review studies focused on a particular set of issues or dimensions for addressing the advancement of mobile collaborative learning. To the best of our knowledge, no review paper has been conducted to investigate the trends of mobile collaborative learning from a global perspective based on a theoretical framework. The aim of this study was therefore to portray the developing status and trends of the mobile collaborative learning research from different dimensions and to gain some valuable information to serve as hints, references, and guidelines for policy making, instructors, and educators by referring to the theory of social constructivism. The following research questions were proposed.

(1) During 2007 to 2016, what is the distribution, amount, and research methodology of mobile collaborative learning?
(2) During 2007 to 2016, what are the learning devices and learning environments for mobile collaborative learning? Compared to the first period (2007–2011), what is the developing trend in the second period (2012–2016)?
(3) During 2007 to 2016, what are the participants, subjects, and measurement issues for mobile collaborative learning? Compared to the first period (2007–2011), what is the developing trend in the second period (2012–2016)?
(4) During 2007 to 2016, what is the collaborative group constitution and application status of collaborative strategies?
(5) During 2007 to 2016, what is the relationship between mobile collaborative learning strategies and measurement issues? What are the features of collaborative learning strategies in the mobile collaborative learning scenarios?

2. Research methods

2.1. Term definition

Several collaborative learning strategies were taken into account in this study: "Learning Together" refers to learning in teams with positive interdependence, group accountability, interactions and so on (Johnson & Johnson, 1975); "Team Games Tournaments" refers to a strategy comprised of four steps, namely whole-class presentation, group discussion, tournament, and group recognition (DeVries & Edwards, 1974); "JigsawII" refers to a strategy which divides class members into groups and breaks the teaching content into pieces which the groups assemble to complete the jigsaw puzzle (Slavin, 1986); "Team Assisted Individualization" is a strategy placing students with different abilities into groups to get them to help one another (Slavin, Leavey, & Madden, 1986); "Student

Teams Achievement Divisions" means engaging learners with different knowledge levels in team-based learning to achieve common learning goals together (Slavin, 1978); "Cooperative Integrated Reading and Composition" is a learning method for teaching reading and writing to students in mixed-ability teams, in which they help each other to achieve their common goals (Stevens, Madden, Slavin, & Farnish, 1987); Group Investigation emphasizes that small groups learn through inquiry and discussion (Sharan & Sharan, 1990); "Academic Controversy" is a learning strategy to engage small groups of students in a controversy, and then guide them to reach a consensus (Johnson & Johnson, 1979); "Think-Pair-Share" is an approach with content-free structures, which consists of three steps, for example, individual study (e.g., reading, thinking), pairing up and sharing opinions, and sharing with the whole class (Kagan, 1989); "Peer Learning" is a strategy whereby students primarily learn from each other (e.g., discussion, observation), in which instruction from teachers is usually absent (O'Donnell & King, 1999); "Group Discussion" refers to the strategy engaging learners in freely discussing with peers without a specific structure, common responsibility, or division of labor.

In addition, u-learning is the abbreviation of ubiquitous learning, usually defined as anywhere and anytime learning using mobile and wireless communication technologies, as defined by Hwang, Tsai, and Yang (2008). In educational contexts, collaboration refers to two or more team members engaging in planning or problem-solving by continuous and interdependent interactions (West, 1990). At last, in this current study, technology-supported means that students learn with technological devices or information technologies to obtain specific learning goals.

2.2. Process of data searching and collection

Based on the suggestions of previous studies, such as Hsu et al. (2012) and Hwang and Tsai (2011), it is important to conduct a review based on quality publications. For literature reviews conducted in relation to education, the Web of Science database has been recommended by several previous studies; therefore, in this study, the Boolean expression ("mobile learning" OR "ubiquitous learning") AND ("collaborative" OR "cooperative" OR "collaboration" OR "cooperative") was used to search for publications from the Web of Science database (https://apps.webofknowledge.com). In order to find literature of high quality, the SCI and SSCI databases were set as the target databases for searching for the literature. Furthermore, the period was set from 2007 to 2016, and the literature types were "article" based on the suggestions of several previous review studies (e.g., Hwang & Tsai, 2011; Lin & Lan, 2015). A total of 112 articles were identified. Following that, the inclusion criteria were established to narrow down the target articles, which means that they must be about mobile collaborative learning, including the development and evaluation of mobile collaborative learning platforms, investigations, teaching activities, theories, experiences, and literature reviews of mobile collaborative learning. Based on the established inclusion criteria, the abstracts of the 112 articles were read and analyzed, and irrelevant articles were excluded. Finally, 90 articles were chosen for inclusion in the analysis. Fig. 1 shows the process and methods of data searching and collection. Fig. 1 shows the process and methods of data searching and collection.

2.3. Data distribution

After content coding and analyzing the 90 articles, the researchers categorized them according to publication year, and performed a preliminary examination of the data sources to see if the definition of mobile collaborative learning was consistent with the general understanding. Fig. 2 shows the data distribution. It can be seen that the amount of mobile collaborative learning literature increased gradually in the 10 years, which fits the regularity of developing new items. Hsu and Ching (2013) searched the research on mobile computing technology-supported collaborative learning published in peer-reviewed journals during the period 2000 to 2011, and a total of nine studies were found. It can be inferred that there was little research about mobile collaborative learning before 2011, which corresponds to the findings of this study. The correctness of the data was proved, and therefore the study could proceed to the next stage of the coding scheme.

2.4. Coding scheme and process

In order to systematically examine the development status and trends of mobile collaborative learning research from 2007 to 2016 from different dimensions, the coding scheme was established from diverse dimensions, including learning devices, learning environment, subjects, research types, measurement issues, group constitution, collaborative learning strategy, and research methods.

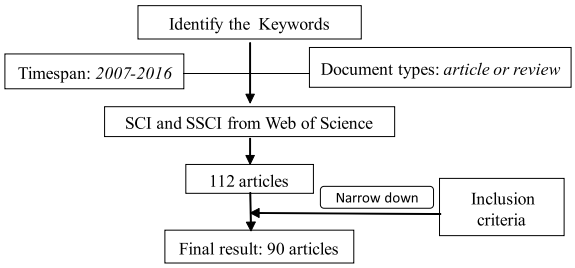

Fig. 1. Process and methods of data searching and collection.

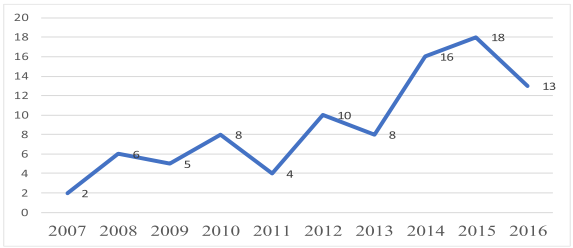

Fig. 2. Distribution status of mobile collaborative learning literature from 2007 to 2016.

(1) Codes for learning devices and learning environment.

The coding scheme of mobile devices was based on Wu et al. (2012), and the investigation of mobile devices was based on Hwang et al. (2008). The coding scheme of mobile learning devices was developed and included wearable devices, smart phones, tablet computers, traditional portable computers or devices, mixed or varied, and non-specified. Moreover, the coding scheme of the learning environment includes classroom or laboratory, school campus, museum library or historical building, ecological area or zoo or garden, science park, others and non-specified.

(2) Codes for research participants and subjects.

The codes for participants and subjects were proposed by Hwang and Tsai (2011). The codes for participants include elementary schools, junior and senior high schools, higher education, teachers, working adults, others and non-specified, while the codes for learning subjects include engineering or computers, science (e.g., physics, chemistry, biology, environmental science or natural science), health, medical or nursing, social science or social studies, arts or design, languages, mathematics, business and management, other and non-specified.

(3) Codes for measurement issues.

This study summarized the research issues and established the codes for the measurement issues, including the technology acceptance model or intention of use, attitudes, motivation and anticipation of effort, self-efficacy, confidence and anticipation performance, satisfaction or interest, cognitive load, learning anxiety, learning performance (cognitive), learning performance (skillful), learning behavior or engagement (including learning path), opinion of learner or learning perception (including interview or open-ended questions), correlation or cause-and-effect analysis (including model value, social influence or influence factor), higher order skills (including problem-solving, meta-cognitive, critical thinking or creativity), collaboration or communication, and other, giving a total of 14 codes.

(4) Codes for collaborative group constitution.

The codes for collaborative group constitution were composed of three sub-codes, namely a period of time for a group, group size, and group members. Johnson and Johnson's (1999) research was referred to and the codes for a period of time for a group included informal group, formal group, and base group. Previous research indicated that the group size of collaborative learning groups was two to six people (Kagan & Kagan, 2009). Accordingly, the codes for group size included small groups (2–3 people), medium groups (4–5 people), large group (more than 5 people), mixed size group, and non-specified. If the group size could be categorized into two or even three codes of small size group, medium size group, and large size group, then it was coded as a mixed size group. The codes for group member selection included random, learning achievement (heterogeneous), learning achievement (homogenous), learning style, other, and non-specified.

(5) Codes for collaborative learning strategies.

Johnson et al. (2000) pointed out eight commonly used collaborative learning strategies. Accordingly, the coding scheme for collaborative learning strategies included learning together, team games tournaments, group investigation, academic controversy, jigsaw II, student team achievement divisions, team assisted individualization, cooperative integrated reading and composition, other, and non-specified.

(6) Codes for research methods.

Pimmer et al. (2016) divided research methods into quantitative, qualitative, and mixed method. Another code, other, was added in the coding scheme.

(7) Codes for research domains.

Based on the contents, in this study, we categorized all articles into software development, instruction and learning, survey activities, and others. Among these, software development means that researchers design or develop a mobile collaborative learning-supported software platform, based on a certain educational need; instruction and learning means that mobile collaborative activities were adopted to measure one or more learning issues, and if one study is to develop software, which also serves as a platform to design learning activities to measure relevant issues, then it can be categorized into instruction and learning; survey activities indicates the opinion survey for learners and teachers, including correlation and causal relationship; others means the theories, experiences, and literature reviews of mobile collaborative learning.

After developing the coding scheme, the two coders had complete communication to ensure their consistent understanding of the coding scheme. Accordingly, three strategies, think-pair-share, group discussion, and peer learning were added to the codes for collaborative learning strategies. Based on the categorization of Johnson et al. the code of think-pair-share was considered as a structured cooperative learning strategy, while group discussion and peer learning were considered as conceptual cooperative learning strategies.

After completing the coding preparation, the two coders started to code independently. After coding, they used SPSS to test the consistency, and the result was 0.973. Then, the coding scheme was examined by a third researcher, a well-known expert in the digital learning domain, who approved of the scheme. After passing the consistency test, the two coders discussed the inconsistent codes and negotiated to reach a consensus.

3. Research results

3.1. Current status and trend of research distribution, quantity, and methods

This section demonstrates the overall current status and developing trend in the mobile collaborative learning research from 2007 to 2016, including the research domain distribution, quantity, and research methods.

Fig. 3 shows that the number of studies increased significantly from 25 in the first period (2007–2011) to 65 in the second period (2012–2016). In addition, in the first period, not much difference was found in the amount of research on software development and instruction and learning. However, in the second period, the amount of research on software development grew slightly, the amount on instruction and learning increased considerably, which also constituted a great part of the total research in the second period, meaning that most educators were dedicated to developing and applying mobile collaborative learning strategies. Furthermore, in the first period, there was merely research investigating mobile collaborative learning, but in the second period, the research on this aspect increased dramatically. On the other hand, those studies in the “other” category, such as review or position papers, or theory investigation of mobile collaborative learning research were situated at a lower developing level.

For the research method aspect, from Fig. 4, it can be seen that, compared to the first period, the amount of research using quantitative analysis and mixed methods increased enormously in the second period, meaning that researchers emphasized the empirical experience in both experimental environments and real scenarios. Besides, although the amount of qualitative research was relatively small, the increasing ratio in the first and second half of the 10 years still reflected a new tendency in the research domain..

3.2. Current status and trend of learning devices and environment

Fig. 5 shows that new technology is widely applied in teaching activities. Compared with the first half of the 10 years, with the rapid development of intelligent mobile technology, smart phones and tablet devices were applied widely in teaching environments in the second half of the 10 years, which also reflects the fact that the latest technology provides better portability, interactivity, and autonomy to meet the needs of mobile learning. Furthermore, diverse technology devices were applied in education simultaneously, which reflects that learners started to use their own mobile devices in learning in the second half of the 10 years (Li, Pow, & Cheung, 2015), or to use their own mobile devices and the ones provided by schools in the learning activities. Compared to the first half of the 10 years, in the second half, the usage of conventional mobile devices decreased slightly but was still widely used, which indicated an

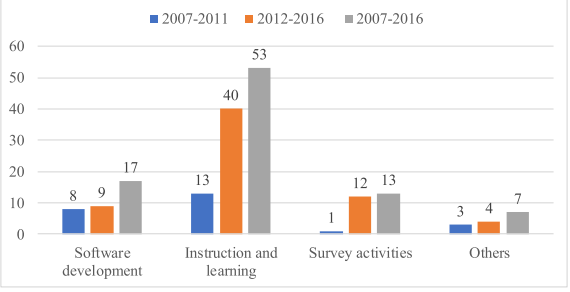

Fig. 3. Research domain distribution of mobile collaborative learning.

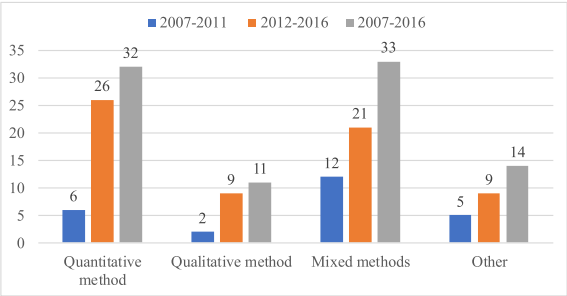

Fig. 4. Research methods in mobile collaborative learning.

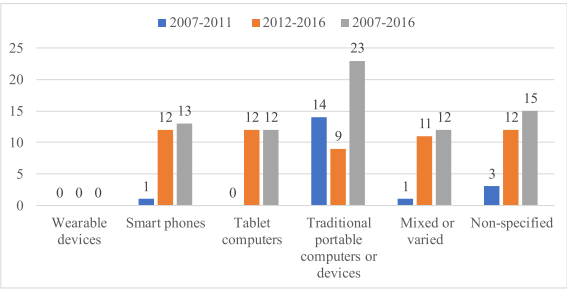

Fig. 5. Mobile devices used in mobile collaborative learning.

era of transition from new to old technology in the second half of the 10 years. Finally, during the decade, no wearable mobile devices were used in the teaching activities, meaning that applying new technology in teaching environments still falls behind the technology development. It is suggested that future education and research can investigate in this direction.

In the learning environment aspect, Fig. 6 shows that although the classroom or laboratory were in the first place in the first and second halves of the 10 years, more collaborative learning activities were conducted outside of the classroom in the second half of the 10 years. Compared to the first half, the research conducted in museums, libraries or historical buildings increased the most in the second half of the 10 years. Research conducted in ecological areas or zoos or gardens also increased. Meanwhile, the research conducted in unconventional teaching environments (others) also occupied a great portion of the studies. These trends reflect that mobile collaborative learning is inclined to be conducted in real life scenarios.

3.3. Developing trends of research participants, subjects, and measurement issues

In the research participant aspect, Fig. 7 shows that from 2007 to 2016, they were mainly higher education students, followed by elementary school students. These two groups received doubled emphasis in the first and second half of the 10 years. Meanwhile, little research was conducted on junior and senior high school students in the first half of the 10 years, but the amount increased in the second half. Furthermore, what is worth noting is that teachers started to receive emphasis in the second half of the 10 years but others (such as adults) received little attention, meaning that the research on mobile collaborative learning has not focused on groups beyond the campus.

To present the distribution of and changes in the subjects of mobile collaborative learning research, the distribution of learning subjects in the first (2007–2011) and second (2012–2016) halves of the 10 years was counted. Meanwhile, the amount in the first half was the criterion to calculate the growth rate of different subjects in the second half. The results are presented in Table 1. First, compared to the first half of the 10 years, the amount of research in social science or social studies increased greatly in the second half, with a growth rate of 1300%, followed by languages with a growth rate of 600%. Besides the research conducted in non-

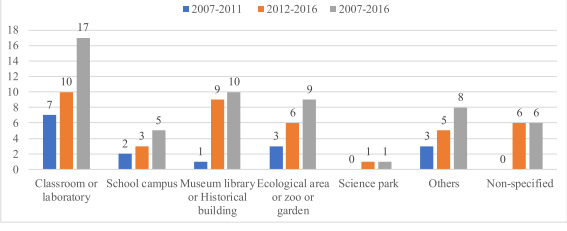

Fig. 6. Learning environment of mobile collaborative learning.

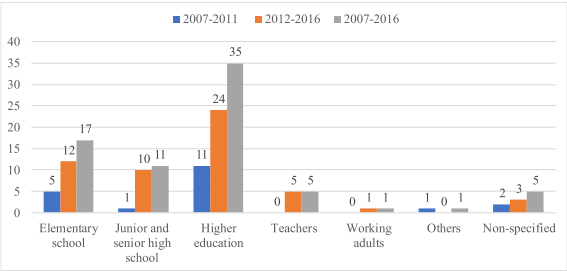

Fig. 7. Participants in mobile collaborative learning research.

Table 1
Distribution and growth rate of learning subjects in mobile collaborative learning from 2007 to 2016.

Learning domains	2007–2011	2012–2016	Growth rate
Social science or Social studies	1	14	1300%
Languages	1	7	600%
Non-specified	2	10	400%
Science	5	12	140%
Arts or design	0	4	NA
Business and Management	0	1	NA
Health Medical or Nursing	0	1	NA
Mathematics	1	1	0
Engineering or Computers	6	5	−16.7%
Others	2	0	−100%

specified subjects, research in science followed with a growth rate of 140%. However, the amount of research in engineering or computers decreased. It was indicated that mobile collaborative learning activities are especially suitable to conduct in the social science subjects, followed by science. Meanwhile, in the recent 5 years, languages and arts or design also received attention, but there was less research in these domains. It is expected that the amount of research in these two subjects will increase enormously. Second, compared to the first half of the 10 years, business and management as well as health, medical, or nursing started to receive attention in the second half of the 10 years, but the amount of research was still small. Mathematics received little attention in these 10 years. Finally, much research was conducted without certain learning subjects, and students' and teachers' opinions and perceptions of mobile collaborative learning were emphasized. The amount of such research increased in the second half of the 10 years.

Exploring the learning issues in the mobile collaborative learning activities is one of the main points of this study. The distribution of learning issues in the first (2007–2011) and second (2012–2016) periods was calculated. Meanwhile, the amount in the first half was the criterion to calculate the growth rate of different learning issues in the second half. The results are presented in Table 2. From the growth rates in the first and second halves of the 10 years, compared to the first half, most learning issues increased greatly. Besides the issues categorized as others, the issues with the top three growth rates were correlation or cause-and-effect analysis, learning behavior or engagement, and learning performance (cognitive), and the issues with the three lowest growth rates were learning performance (skillful), technology acceptance model or intention of use, and satisfaction or interest. From the trend, it can be found that in the second half of the 10 years, researchers started to emphasize the learning or cognitive process of collaborative learning and to investigate the relationship between learning process and scores (Li et al., 2015). In the first half of the 10 years, there

Table 2
Distribution and growth rate of research issues in mobile collaborative learning from 2007 to 2016.

Learning outcomes	2007–2011	2012–2016	Growth rate
Technology acceptance model or intention of use	13	19	46.2%
Opinion of Learner or Learning perception	12	20	66.7%
Learning performance (Cognitive)	6	25	316.7%
Collaboration or Communication	7	20	185.7%
Satisfaction or Interest	9	15	66.7%
Correlation or Cause-and-effect Analysis	2	21	950.0%
Attitude, Motivation or Anticipation of effort	6	15	150.0%
Learning behavior or Engagement	3	14	366.7%
Higher order skills	3	9	200.0%
Learning performance (skillful)	4	5	25.0%
Self-efficacy, Confidence or Anticipation performance	2	7	250.0%
Cognitive load	1	2	100%
Learning anxiety	0	1	NA
Other	3	16	433.3%

was much research on the technology acceptance model or intention of use and satisfaction or interest, but the amount of research on these issues grew the least in the second half of the 10 years. From the overall amount in the 10 years, the technology acceptance model or intention of use, opinions of learners or learning perceptions, and learning performance (cognitive) were the top three issues receiving emphasis from researchers, and self-efficacy, confidence or anticipation performance, cognitive load, and learning anxiety were the least emphasized issues. From learning performance (cognitive and skillful) and higher order skills, researchers emphasized cognitive level more than skill level, as shown in the amount and growth rate, which indicated that the focus on the skill level of mobile collaborative learning should be emphasized. Furthermore, the emphasis on higher order skills was low. From the importance of collaboration or communication, the amount ranked number 4 among all issues, and the growth rate was 185.7%, indicating that researchers paid more attention to collaboration or communication in the mobile collaborative learning activities. From investigating the effects of mobile collaborative learning, the amount of research on correlation or cause-and-effect analysis ranked number 6 among all issues and had the highest growth rate of 950%, which also ranked number 2 in the amount of research in the second half of the 10 years. This result indicated that the issue of correlation or cause-and-effect analysis in mobile collaborative learning is the main point in the research of the recent 5 years. Finally, it was found that the amount and growth rate of the issues categorized as other are worth paying attention to. In this category, researchers paid attention to various types of learning issues. For instance, Melero, Hernández-Leo, and Manatunga (2015) investigated the effects of numbers of group members on learning engagement and grade, and concluded that, compared to a group with five members, a group with four members showed higher learning engagement, but the size of the group would not affect the learning performance of the individuals. Uzunboylu, Cavus, and Ercag (2009) explored the effects of using mobile collaborative learning to boost students' environmental awareness.

3.4. Current status of collaborative learning group constitution and strategy application

This section presents the current status of mobile collaborative learning group design and strategy application in terms of group member selection, group size, and group duration.

For the group member selection aspect, there were 27 studies which did not specify how to select learners to constitute a learning group, eight studies adopted random grouping by teachers, 10 studies adopted heterogeneous grouping based on learners' grades or capabilities, one study adopted homogeneous grouping based on learners' grades or capabilities, and seven studies adopted other approaches to group students. For instance, Huang and Wu (2011) used portfolio-based heterogeneous grouping, and Lee, Drake, et al. (2016) and Lee, Parsons, et al. (2016) adopted knowledge-based heterogeneous grouping. Two studies conducted by Sun and Shen (2014) and Liao, Huang, Chen, and Huang (2015) also adopted heterogeneous grouping, but the criterion was not specified. The research conducted by Ting (2013), and Chiang, Yang, and Hwang (2014), and Reychav, Ndicu, and Wu (2016) adopted a grouping approach involving students' selection.

It can be found that random grouping still occupied a great portion of the research, but when researchers or teachers wanted to group students based on certain traits, heterogeneous grouping was frequently used. While using heterogeneous grouping, students' capabilities and grades were mostly used as the criterion. On the other hand, no research conducted grouping according to members' learning styles.

As for the group size, 17 studies did not report group size, 14 studies adopted small groups, followed by medium (N = 7), large (N = 7), and mixed size groups (N = 8). It was found that the researchers in the mobile collaborative learning domain were inclined to constitute small learning groups. Such a result corresponds to the research of Bertucci et al. (2010).

For the group duration aspect, it is found that most research adopted formal groups, meaning that the collaborative learning activities in the research lasted for one session or even weeks. Group responsibility, interdependency, and mutual learning goals in groups were stressed. Some studies adopted informal groups, meaning that the researchers focused on temporary and short-term learning groups to help students understand and internalize the knowledge. Few studies adopted base groups, meaning that there was little research using mobile collaborative learning activities to help students build and develop long-term collaborative learning relationships to achieve the goals of mutually monitoring, boosting, and improving. It is suggested that future studies can work on this aspect.

The studies which adopted collaborative learning strategies in the target literature were counted, as shown in Table 3. It can be found that conceptual cooperative learning strategies occupied a majority of the mobile collaborative learning activities, reflecting the openness of cooperative learning activities in the mobile collaborative learning, which also corresponds to learner-centered theory in mobile learning. That is, the researchers in the mobile collaborative learning domain emphasized designing unstructured cooperative learning missions, which granted more rights of learning actively in the process.

3.5. Relations between collaborative learning strategies and measurement issues

Table 4 shows that in developing learners' cognition, most cooperative learning strategies can be used, among which learning together was used the most, followed by peer learning and group investigation. It was discovered that most researchers chose to use conceptual cooperative learning strategies, which made students shoulder more autonomy, actively interact with their learning companions, and gain knowledge via unstructured learning activities. Meanwhile, structured cooperative learning strategies can also be adopted, and with the relatively structured learning guidance, students can gain and understand knowledge with learning companions.

While developing learners' skills, Table 5 shows that researchers adopted conceptual cooperative learning strategies such as group investigation, learning together, and peer learning. Structured cooperative learning strategies were not adopted, meaning that

Table 3
Distribution of cooperative learning strategies in the mobile collaborative learning research from 2007 to 2016.

Classification of Cooperative learning strategies	Number of studies
Structured cooperative learning strategies	
Jigsaw II	5
Think-Pair-Share	4
Team Games Tournaments	1
Team Assisted Individualization	0
Student Teams Achievement Divisions	0
Cooperative Integrated Reading and Composition	0
Conceptual cooperative learning strategies	
Learning Together	16
Group Investigation	11
Peer Learning	8
Group Discussion	7
Academic Controversy	1

Table 4
Cooperative learning strategies adopted in developing learners' cognition.

Classification	Collaborative learning strategies	Number of studies
Conceptual cooperative learning	Learning Together	11
	Peer learning	6
	Group Investigation	4
	Academic Controversy	1
	Group discussion	1
Structured cooperative learning	Jigsaw	3
	Think-pair-share	3
	Team Games Tournaments	1

Table 5
Cooperative learning strategies adopted for developing learners' skills.

Classification	Collaborative learning strategies	Number of studies
Conceptual cooperative learning	Group Investigation	3
	Learning Together	3
	Peer learning	2

researchers arranged learners in relatively open learning activities such as group inquiry activities or learning activities with certain items.

While developing learners' higher order skills, most researchers adopted conceptual cooperative learning strategies, as shown in Table 6. Only two researchers used Jigsaw II in the structured cooperative learning strategies.

While boosting learners' collaboration or communication, the cooperative learning strategies adopted are listed in Table 7. Most researchers adopted conceptual cooperative learning strategies among which learning together and group investigation were used the most.

In summary, it can be found that while developing students' knowledge, skills, collaboration and communication skills, and higher order skills, most researchers used the conceptual cooperative learning strategies, such as learning together and group investigation. According to Johnson et al. (2000), learning together is at the lowest structure level, followed by academic controversy and group investigation. That is, these strategies engage students in open-ended learning environments which enable them to learn in

Table 6
Cooperative learning strategies adopted to develop learners' higher order skills.

Classification	Collaborative learning strategies	Number of studies
Conceptual cooperative learning	Learning Together	4
	Peer learning	2
	Academic Controversy	1
	group discussion	1
	Group Investigation	1
Structured cooperative learning	Jigsaw II	2

Table 7
Cooperative learning strategies adopted to develop learners' collaboration and communication.

Classification	Collaborative learning strategies	Number of studies
Conceptual cooperative learning	Learning Together	9
	Group Investigation	6
	Group discussion	3
	Peer learning	3
Structured cooperative learning	Think-pair-share	1
	Team Games Tournaments	1
	Jigsaw II	1

a more flexible and interactive mode with diverse alternatives to socially and epistemologically construct knowledge (Tsai, 2004).

4. Discussion

4.1. Research distribution, quantity, and methods

In the past decade, especially in the recent 5 years, the educational value of collaborative learning in mobile learning environments has received increasing emphasis. Hwang et al. (2008) pointed out the value and potential of integrating mobile devices and collaborative learning. After that, many researchers started to explore how to develop collaborative learning activities to boost students' learning in mobile learning environments (Liu, Tan, & Chu, 2009). Besides conducting cooperative learning activities in mobile learning environments, survey research began to be popular in the past 5 years, meaning that educational researchers started to emphasize individuals' learning perceptions and experience, including their attitudes or opinions, learning behaviors, and the correlations of factors in collaborative learning. In the research method aspect, Pimmer et al. (2016) believed that to deeply understand the emerging phenonemon of mobile learning, it is necessary to consider not only the quantitative method but also the qualitative method and mixed methods. The findings of this study correspond to such an opinion. The mobile collaborative learning which happened outside of the classroom had more bountiful and complex interactions; therefore, simply manipulating some variables to control others might not be sufficient to accurately unveil the causal relationship of mobile collaborative learning. However, the qualitative method or mixed methods emphasize the overall protection of learning scenarios and the viewpoints of learners to demonstrate the meaning of learning, and also stress the humanity and caring of the new learning mode corresponding to the contents and directions of requests proposed by educational development in the area.

4.2. Learning devices and environments

Mobile devices and learning environment play important roles in the mobile collaborative learning activities. Much research has discovered that the promotion of learning effects should be attributed to the support of mobile devices in learning because the just-in-time learning affordances of mobile devices provides learners with important assistance (Ekanayake & Wishart, 2015; Liu, Geurtz, Karam, Navarrete, & Scordino, 2013). The affordances of learning devices can be fully used in the learning environment to build an authentic teaching scenario across time and space, plentiful resources, and interactive convenience from the real world. From the application distribution and developing trend of mobile devices, smartphones and tablet computers are the devices with new technology which were used widely in the second half of the 10 years. Klopfer, Squire, and Jenkins (2002) portrayed the unique education affordances of PDA mobile devices, meaning that portability, social interactivity, context sensitivity, connectivity, and individuality can be better supported and presented on new devices; besides, it also boosted the shift in mobile collaborative learning activities from conventional classrooms to real living scenarios (Song, 2014). Furthermore, learners started to use their own mobile devices in learning (Li et al., 2015), which presents the intention and behaviors of autonomous learning and ubiquitous learning for mobile learners. However, no research on using wearable devices in mobile collaborative learning was conducted. There is a little research on using wearable devices in the mobile learning domain. For instance, Lee, Drake, and Thayne (2016) used wearable devices to help fifth graders develop statistical thinking in their daily lives, and it was found that, compared to conventional mobile devices, using wearable devices improved students' statistical thinking in certain dimensions, such as conceptions of statistics, modeling variability, and informal inferencing. Although similar evidence is still limited, the educational value of wearable devices can be found, and it can help learning become gradually immersed in students' daily lives; the concept of autonomous learning and ubiquitous learning would be further carried out. The development of learning devices is closely linked to the development of learning environments. In the second half of the 10 years, the amount of literature on mobile collaborative learning activities conducted outside of the classroom went greatly beyond that conducted inside the classroom, which at some point reflects that the five unique educational affordances proposed by Klopfer et al. (2002) were implemented in the collaborative learning activities outside of the classroom. It also confirmed the developing prediction of collaborative learning activities in context-aware ubiquitous learning and context-aware u-learning by Hwang et al. (2008).

4.3. Research participants, subjects, and measurement issues

From the research participant aspect, little research was conducted on teachers and working adults. Researchers have pointed out that mobile technology provides many new opportunities for education, which changes teachers' attitudes towards applying technology; thus, cultivating and elevating teachers' educational practices of technology is equally important to developing their professionalism (Ekanayake & Wishart, 2015). Despite the rapid growth in mobile collaborative learning at colleges and elementary as well as high schools, the research for teachers and learners outside of campus, such as training for different fields, still needs to be improved.

In terms of the research subject aspect, there is little research on arts or design, business and management, health, medical or nursing, and mathematics, but mobile collaborative learning in these subjects would still be of great educational value. Crompton, Burke, and Gregory (2017) believed that art is a visualized subject and mobile devices offer many affordances to apply in art teaching activities. Lai and Hwang (2015) developed an interactive peer-assessment criteria development approach to help elementary school students use mobile devices to learn and reflect on the art works in art courses and hence their learning grades, motivation, and metacognitive intention increased significantly. Lee, Drake, et al. (2016) and Lee, Parsons, et al. (2016) developed a mobile learning game to support students when playing the roles of business consultants and to develop learners' cooperative critical thinking. It can be found that these subjects all included higher order thinking (i.e, problem-solving, critical thinking, and creativity).

In terms of the distribution and development of research issues, little attention was paid to the issues of higher order skills, learning performance (skillful), self-efficacy, confidence or anticipation performance, cognitive load, and learning anxiety; the reasons might be that the cultivation of skills and higher order skills need a longer time, and measuring the abilities needs proper tools and approaches (Song, 2014). The reason why few research issues are about cognitive load and learning anxiety might be due to the research subjects. Most subjects in mobile collaborative learning research were science, including natural science and social science. Learning mostly happened in relaxing and free scenarios; however, in mathematics activities, learners were situated in a totally different context with challenging tasks, which could increase their learning anxiety (Ramirez, Gunderson, Levine, & Beilock, 2013). Therefore, it is important to conduct mobile collaborative learning studies to explore the learning issues in mathematics or other subjects in the future.

4.4. Group composition and strategy application

Researchers have indicated that different group composition methods could have different effects on the learning results and behaviors in collaborative learning activities (AbuSeileek, 2012; Amara, Macedo, Bendella, & Santos, 2016; Melero et al., 2015). In terms of group member selection, most research used a heterogeneous grouping method, based on learners' knowledge levels, to keep students with different learning achievement levels in one group to maximize their learning outcomes. Much research adopted the random grouping method, which is beneficial for creating excitement for group members and improving class building (Kagan, 1994). No research grouped students based on cognitive styles or learning styles. It is therefore encouraged to conduct research on this aspect. Regarding the member selection issue, Antil, Jenkins, Wayne, and Vadasy (1998) interviewed 85 elementary school teachers and found that most would choose heterogeneous grouping, but sometimes they would also choose other grouping methods, such as random grouping, students' free selection, and convenient grouping. Ability composition was not what they were concerned about or it would not affect their decision of using collaborative learning strategies, which was also confirmed by the researchers of this study. It was found that most research adopted different group member selection strategies, but the difference was not examined.

In the arrangement of group size, some researchers believed that four people in a group is the most ideal group size because it allows pair work and hence encourages active participation (Kagan, 1994). Antil et al. (1998) also discovered that teachers sometimes chose learning partners (pairs) and sometimes small groups (usually four students). However, it was found that researchers in the mobile collaborative learning domain usually adopted two to three people in a group. Slavin (1987) also considered that two to three people in a group outperformed four or more, but there are also many methods for adopting four to five people in a group, more than five people in a group, or groups without size limitation, meaning that researchers in the mobile collaborative learning domain have been inclined to establish smaller collaborative groups but they also attempted to try other grouping methods. The reason might be that in the mobile collaborative learning activities, students' learning motivation might be stronger. Although some group members might be redundant or temporarily alone due to the arrangement of pairing during the activity, they can use the mobile devices on hand to conduct temporary self-learning. Therefore, the effects of group size might not be as great as those in the conventional environment, but it is also encouraged to investigate and clarify this issue.

From the group duration period, most research adopted formal groups, meaning that most mobile collaborative learning was to deliver certain learning contents, and it usually lasted one or two class periods to a few weeks; during the process, students completed specific missions for common goals (Johnson & Johnson, 1999). Little research adopted an informal group design, in which students constituted short-term and temporary learning groups for a joint learning goal (Johnson & Johnson, 1999); for instance, students were assigned to temporary learning groups to discuss the encountered problems during the learning process or share information to reinforce their understanding of the knowledge. Therefore, formal groups emphasized mutual understanding of knowledge and informal groups focused on personal understanding of the knowledge. Furthermore, there is little research adopting base group design, meaning that the research on students' long-term collaborative learning is still lacking. This kind of research can cultivate students' collaborative learning intention, habits, respect of others, and responsibility of learning. Students can also be cultivated as citizens with collaboration, skills, and responsibilities.

Regarding the collaborative learning strategies aspect, applying conceptual cooperative learning strategies constituted the

majority of the mobile collaborative learning activities. After interviewing 85 elementary school teachers, Antil et al. (1998) found that 33% of them believed that, compared to those “more formal” strategies, the collaborative learning strategies used in their classes were informal. Besides, they considered that collaborative learning is a sophisticated way, which indicates that the teachers sub-consciously intended to choose conceptual cooperative learning strategies. Additionally, the mobile collaborative learning activities were mostly conducted outside of the classroom, learning tasks were unstructured, teaching methods were more student-centered, and mobile learning devices were beneficial to improving social interaction among peers; therefore, it is reasonable to find that most mobile collaborative learning activities adopted conceptual cooperative learning strategies.

Furthermore, from the students' viewpoints in the mobile collaborative learning activities, So, Tan, and Tay (2012) found that although students leaned towards collaborative learning in their attitudes, they leaned towards cooperative learning in their behaviors. For instance, they tended to break down the learning missions and conquer them (“divide and conquer”). Therefore, while applying conceptual cooperative learning strategies in mobile collaborative learning activities, it is necessary to design the activities in detail so as to guide students to conduct co-constructed learning and avoid some learning behaviors such as Drill and Practice (So et al., 2012). For instance, Hwang et al. (2011) adopted the collaboraitve learning strategy with mind mapping to help students gain knowledge in a butterfly ecology garden, and the research proved that, compared to conventional u-learning, this approach can significantly improve students’ attitudes, self- and group-efficiency, and grades. If the research only adopted cooperative learning strategies but did not design them in detail, the results might be different, as many previous researchers have mentioned that, in collaborative learning, merely letting students sit together is insufficient (Kreijns, Kirschner, & Jochems, 2003; Slavin, 1987).

4.5. Cooperative learning strategies for measurement issues

While using cooperative learning strategies in collaborative learning activities to develop learners' knowledge, skills, higher order skills, and cooperation or communication, most researchers adopted conceptual cooperative learning strategies rather than structured cooperative learning strategies. Slavin (1996) considered that the structured cooperative learning missions do not need group goals and individual accountability. Teachers can use a structured sequence of activities to motivate group members directly to help each other to complete the learning missions, but most cooperative learning missions like this are effective only for lower level and rote skills. Those cooperative methods using group goals and individual accountability would motivate group members indirectly to help each other. Based on Slavin's viewpoints, in conceptual cooperative learning strategy activities, students in groups would try to achieve mutual learning goals and shoulder corresponding responsibilities. Such scenarios would generate more internal motivation and make students more actively involved in the learning activities, and hence higher order capabilities can be developed.

4.6. Framework and suggestions for future research

Based on the results of this review study, it was found that, while considering students’ knowledge and skill development as well as their collaboration and communication and higher order thinking performances, most researchers tended to employ conceptual cooperative learning strategies, which enable students to learn in a more flexible and interactive manner to construct knowledge.

From the aspect of social constructivism, a conceptual framework of mobile collaborative learning is proposed based on the findings of this study, as shown in Fig. 8. When learners study in groups with the help of mobile technologies, they have more chances to interact with abundant information, peers and experts from society anywhere and anytime, which is beneficial to them for constructing meaningful knowledge by handling, thinking, and reflecting on the diverse information and opinions. As indicated by Tsai (2004), when the learners’ social interactions are appropriately processed, such as adopting suitable collaborative learning strategies to facilitate more active, fluent, and thoughtful discussions, they have opportunities to reflect on various facets of specific knowledge and theories. This enables them to have great chances to develop beliefs about the nature of knowledge and learning. Furthermore, if learners study in more open environments (e.g., museum libraries, ecological areas) with more flexible, open collaborative learning strategies, they are immersed in authentic real-life situations, and are exposed to open-ended, controversial problems, and thus could be encouraged to conduct interactions deeply at micro (such as interpersonal interaction, intra-group

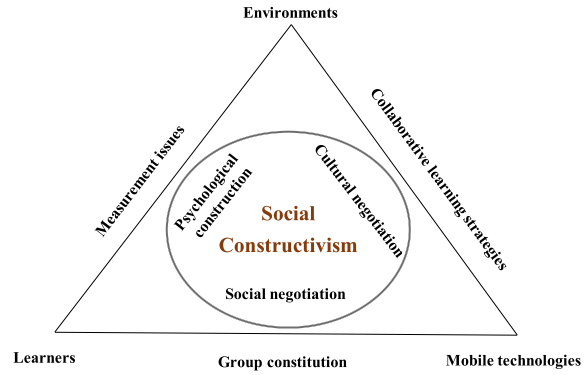

Fig. 8. The conceptual framework of mobile collaborative learning.

interaction, self-reflection) and macro (inter-group interaction, interaction between human and real/historical environments, etc.) levels of social interaction. When situated in cross-cultural contexts, cross-cultural collisions could engage students in reconstructing knowledge and epistemological beliefs under the constant shifting between individual monologues in the local culture and negotiation with the foreign cultures.

Based on the framework and the findings, the following suggestions for future studies are given:

(1) New mobile technologies could affect learners' perceptions, outcomes, and interactive behaviors in collaborative learning activities. Therefore, it is important to investigate the impacts of those innovative technologies, such as wearable devices, on students' learning performances and behaviors from different aspects. For example, how can those new mobile technology-supported collaborative learning approaches affect students' self-learning, collaborative learning, and life-long learning conceptions and performances. How can researchers or teachers design activities to engage students in more meaningful and authentic collaborative learning contexts to provide them with better chances to connect the learning content with real-life experiences, and hence construct knowledge and develop higher order thinking competences.
(2) In addition to considering the needs of students, it is also important to investigate how collaborative mobile learning approaches can benefit teachers and working adults. From the review results, there is a lack of mobile collaborative studies in the domains of professional development and enterprise training.
(3) A large portion of the current studies focused on several subjects, such as social science or natural science, while little research was related to arts or design, business and management, health, medical or nursing, and mathematics. Therefore, it is challenging and important to incorporate mobile collaborative learning approaches into these subjects to explore how the approaches can benefit learners from various perspectives, such as learning attitudes, interests, perceptions, learning performance, and affective factors. Research on issues such as higher order thinking, learning performance (cognition and skill), and self-efficacy is therefore recommended.
(4) It is also important to take individual learners' personal factors into account when conducting mobile collaborative learning activities. Therefore, it is suggested that future research could take those seldom-considered personal factors, such as learning styles or cognitive styles, into account. These personal factors can be considered in the group member selection stage or the learning stage.
(5) Investigation of students' long-term mobile collaborative learning performances and behaviors is another important research issue to be highlighted since few studies have been conducted using long-term activities.
(6) While adopting structured cooperative learning strategies, such as think-pair-share, team games tournaments, and Jigsaw II, it is challenging and important to incorporate additional strategies to assist students in establishing mutual group goals and learning responsibilities in groups, and to encourage and support learners' social interactions and self-reflection.

In addition, from the review results, it was found that an increasing number of studies are being conducted outside of the classroom, such as at ecological zoos, historical buildings, and on school campuses. Moreover, several emerging modes of mobile collaborative learning, such as developing contextual mobile collaborative learning environments with sensing technologies and designing cross-cultural mobile collaborative learning activities are noted. Apart from continuing to propel the emerging mobile collaborative learning modes, it is also important to develop or refine learning strategies to more effectively guide students to learn in such emerging mobile collaborative learning contexts as well as investigating the effects of the learning modes on students' performances from relevant but seldom discussed perspectives, such as their social negotiation skills as well as higher order thinking competences. Other issues, such as the impacts of emerging mobile technologies and innovative group constitutions, are also worth studying.

5. Conclusions

Mobile technologies provide several advantages, such as portability, social interactivity, context sensitivity, connectivity, and individuality (Klopfer et al., 2002), which facilitate seamless social interactions; therefore, engaging students in social and situated learning contexts to encourage them to learn collaboratively with peers via mobile technologies has attracted much attention from educational researchers (Ryu & Parsons, 2012).

The educational affordances of mobile collaborative learning are demonstrated in this study, such as supporting ubiquitous learning, guiding by diverse cooperative strategies, more interpersonal social interaction, facilitating context-based learning, cultivating self-regulated learning and self-reflection, and fostering cross-cultural interaction. Thus, this study demonstrates that, compared to internet-based learning, mobile-based collaborative learning is better able to serve as cognitive, metacognitive, and epistemological tools for students' understanding and conception transformation. A framework is proposed accordingly to show that mobile collaborative learning could be a good response to Tsai's (2004) assertions regarding social constructivism, that is, that learners make progress from social interaction with a variety of information, and with peers and experts with diverse perspectives, from which they construct meaningful knowledge, make reflections, and obtain advanced epistemology by developing evaluative standards and explanatory models for judging information and knowledge. In sum, mobile collaborative learning is a potential learning mode to facilitate knowledge acquisition, metacognition skills, and epistemological beliefs via engaging students in learning collaboratively.

From the review results and the above discussion, it was found that mobile collaborative learning is a rapidly growing research field. It is worth investigating the impacts of mobile collaborative learning in different contexts and from various perspectives with

emerging technologies. Additionally, it is important to reinforce the research on the process of learners' knowledge construction as well as their perceptions and behaviors in collaborative learning processes. Based on the review results and the proposed framework, it is expected that this study can be a good reference for researchers in relevant fields when designing future studies by taking those elements of mobile collaborative learning and the theory of social constructivism into account.

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References

AbuSeileek, A. F. (2012). The effect of computer-assisted cooperative learning methods and group size on the EFL learners' achievement in communication skills. *Computers & Education, 58*(1), 231–239.
Amara, S., Macedo, J., Bendella, F., & Santos, A. (2016). Group formation in mobile computer supported collaborative learning contexts: A systematic literature review. *Educational Technology & Society, 19*(2), 258–273.
Andrews, T. (2012). What is social constructionism. *Grounded theory review, 11*(1), 39–46.
Antil, L. R., Jenkins, J. R., Wayne, S. K., & Vadasy, P. F. (1998). Cooperative learning: Prevalence, conceptualizations, and the relation between research and practice. *American Educational Research Journal, 35*(3), 419–454.
Bertucci, A., Conte, S., Johnson, D. W., & Johnson, R. T. (2010). The impact of size of cooperative group on achievement, social support, and self-esteem. *The Journal of General Psychology, 137*(3), 256–272.
Chiang, T. H., Yang, S. J., & Hwang, G. J. (2014). Students' online interactive patterns in augmented reality-based inquiry activities. *Computers & Education, 78*, 97–108.
Cole, M., John-Steiner, V., Scribner, S., & Souberman, E. (1978). In L. S. Vygotsky (Ed.). *Mind in society: The development of higher psychological processes*. Oxford, England: Harvard U Press.
Crompton, H., Burke, D., & Gregory, K. H. (2017). The use of mobile learning in PK-12 education: A systematic review. *Computers & Education, 110*, 51–63.
DeVries, D. L., & Edwards, K. J. (1974). Student teams and learning games: Their effects on cross-race and cross-sex interaction. *Journal of Educational Psychology, 66*(5), 741–749.
Ekanayake, S. Y., & Wishart, J. (2015). Integrating mobile phones into teaching and learning: A case study of teacher training through professional development workshops. *British Journal of Educational Technology, 46*(1), 173–189.
Hsu, Y. C., & Ching, Y. H. (2013). Mobile computer-supported collaborative learning: A review of experimental research. *British Journal of Educational Technology, 44*(5), E111–E114.
Hsu, Y. C., Ho, H. N. J., Tsai, C. C., Hwang, G. J., Chu, H. C., Wang, C. Y., et al. (2012). Research trends in technology-based learning from 2000 to 2009: A content analysis of publications in selected journals. *Educational Technology & Society, 15*(2), 354–370.
Huang, Y.-M., & Wu, T.-T. (2011). A systematic approach for learner group composition utilizing U-Learning portfolio. *Educational Technology & Society, 14*(3), 102–117.
Hwang, G. J., Shi, Y. R., & Chu, H. C. (2011). A concept map approach to developing collaborative Mindtools for context-aware ubiquitous learning. *British Journal of Educational Technology, 42*(5), 778–789.
Hwang, G. J., & Tsai, C. C. (2011). Research trends in mobile and ubiquitous learning: A review of publications in selected journals from 2001 to 2010. *British Journal of Educational Technology, 42*(4), E65–E70.
Hwang, G. J., Tsai, C. C., & Yang, S. J. H. (2008). Criteria, strategies and research issues of context-aware ubiquitous learning. *Educational Technology & Society, 11*(2), 81–91.
Johnson, D. W., & Johnson, R. T. (1975). *Learning together and alone: Cooperative, competitive, and individualistic learning.* Boston: Allyn & Bacon.
Johnson, D. W., & Johnson, R. T. (1979). Conflict in the classroom: Controversy and learning. *Review of Educational Research, 49*(1), 51–69.
Johnson, D. W., & Johnson, R. T. (1999). Making cooperative learning work. *Theory into practice, 38*(2), 67–73.
Johnson, D. W., Johnson, R. T., & Smith, K. (2007). The state of cooperative learning in postsecondary and professional settings. *Educational Psychology Review, 19*(1), 15–29.
Johnson, D. W., Johnson, R. T., & Stanne, M. B. (2000). *Cooperative learning methods: A meta-analysis.* Minneapolis: University of Minnesota. Retrieved from https://pdfs.semanticscholar.org/93e9/97fd0e883cf7cceb3b1b612096c27aa40f90.pdf.
Kagan, S. (1989). The structural approach to cooperative learning. *Educational Leadership, 47*(4), 12–15.
Kagan, S. (1994). *Cooperative learning, Vol. 2*. San Juan Capistrano, CA: Kagan Cooperative Learning.
Kagan, S., & Kagan, M. (2009). *Kagan cooperative learning.* San Clemente, CA: Kagan Publishing.
Klopfer, E., Squire, K., & Jenkins, H. (2002). Environmental detectives: PDAs as a window into a virtual simulated world. *Wireless and mobile technologies in education, 2002. Proceedings. IEEE international workshop on* (pp. 95–98). IEEE.
Kreijns, K., Kirschner, P. A., & Jochems, W. (2003). Identifying the pitfalls for social interaction in computer-supported collaborative learning environments: A review of the research. *Computers in Human Behavior, 19*(3), 335–353.
Lai, C. L., & Hwang, G. J. (2015). An interactive peer-assessment criteria development approach to improving students' art design performance using handheld devices. *Computers & Education, 85*, 149–159.
Lee, V. R., Drake, J. R., & Thayne, J. L. (2016). Appropriating quantified self technologies to support elementary statistical teaching and learning. *Ieee Transactions on Learning Technologies, 9*(4), 354–365.
Lee, H., Parsons, D., Kwon, G., Kim, J., Petrova, K., Jeong, E., et al. (2016). Cooperation begins: Encouraging critical thinking skills through cooperative reciprocity using a mobile learning game. *Computers & Education, 97*, 97–115.
Liao, Y. W., Huang, Y. M., Chen, H. C., & Huang, S. H. (2015). Exploring the antecedents of collaborative learning performance over social networking sites in a ubiquitous learning context. *Computers in Human Behavior, 43*, 313–323.
Lin, T. J., & Lan, Y. J. (2015). Language learning in virtual reality Environments: Past, present, and future. *Educational Technology & Society, 18*(4), 486–497.
Li, S. C., Pow, J. W. C., & Cheung, W. C. (2015). A delineation of the cognitive processes manifested in a social annotation environment. *Journal of Computer Assisted Learning, 31*(1), 1–13.
Liu, M., Geurtz, R., Karam, A., Navarrete, C., & Scordino, R. (2013). Research on mobile learning in adult education. In W. Kinuthia, & S. Marshall (Eds.). *On the Move: Mobile learning for development.* Charlotte, NC: Information Age Publishing.
Liu, T.-Y., Tan, T.-H., & Chu, Y.-L. (2009). Outdoor natural science learning with an RFID-supported immersive ubiquitous learning environment. *Educational Technology & Society, 12*(4), 161–175.
Melero, J., Hernández-Leo, D., & Manatunga, K. (2015). Group-based mobile learning: Do group size and sharing mobile devices matter? *Computers in Human Behavior, 44*, 377–385.
Neber, H., Finsterwald, M., & Urban, N. (2001). Cooperative learning with gifted and high-achieving students: A review and meta-analyses of 12 studies. *High Ability Studies, 12*(2), 199–214.
O'Donnell, A. M., & King, A. (1999). *Cognitive perspectives on peer learning.* Mahwah, NJ: Erlbaum.

Panitz, T. (1999). Collaborative versus cooperative learning: A comparison of the two concepts which will help us understand the underlying nature of interactive learning. *Active Learning, 13*.
Pfister, H. R., & Oehl, M. (2009). The impact of goal focus, task type and group size on synchronous net-based collaborative learning discourses. *Journal of Computer Assisted Learning, 25*(2), 161–176.
Pimmer, C., Mateescu, M., & Grohbiel, U. (2016). Mobile and ubiquitous learning in higher education settings. A systematic review of empirical studies. *Computers in Human Behavior, 63*, 490–501.
Ramirez, G., Gunderson, E. A., Levine, S. C., & Beilock, S. L. (2013). Math anxiety, working memory, and math achievement in early elementary school. *Journal of Cognition and Development, 14*, 187–202.
Reychav, I., Ndicu, M., & Wu, D. (2016). Leveraging social networks in the adoption of mobile technologies for collaboration. *Computers in Human Behavior, 58*, 443–453.
Ryu, H., & Parsons, D. (2012). Risky business or sharing the load? Social flow in collaborative mobile learning. *Computers & Education, 58*, 707–720.
Sharan, S. (1980). Cooperative learning in small groups: Recent methods and effects on achievement, attitudes, and ethnic relations. *Review of Educational Research, 50*(2), 241–271.
Sharan, Y., & Sharan, S. (1990). Group investigation expands cooperative learning. *Educational Leadership, 47*(4), 17–21.
Sharples, M. (2000). The design of personal mobile technologies for lifelong learning. *Computers & Education, 34*(3), 177–193.
Slavin, R. E. (1978). Student teams and achievement divisions. *Journal of Research & Development in Education, 12*(1), 39–49.
Slavin, R. E. (1986). *Using student team learning* (3rd ed.). Baltimore, Maryland: The Johns Hopkins University.
Slavin, R. E. (1987). Ability grouping and student achievement in elementary schools: A best-evidence synthesis. *Review of Educational Research, 57*(3), 293–336.
Slavin, R. E. (1996). Research on cooperative learning and achievement: What we know, what we need to know. *Contemporary Educational Psychology, 21*(1), 43–69.
Slavin, R. E. (2014). Cooperative learning and academic Achievement: Why does groupwork work? *Anales de Psicología/Annals of Psychology, 30*(3), 785–791.
Slavin, R. E., Leavey, M., & Madden, N. A. (1986). *Team accelerated instruction: Mathematics.* Watertown, MA: Charlesbridge.
Song, Y. (2014). Methodological issues in mobile computer-supported collaborative learning (mCSCL): What methods, what to measure and when to measure? *Educational Technology & Society, 17*(4), 33–48.
So, H. J., Tan, E., & Tay, J. (2012). Collaborative mobile learning in situ from knowledge building perspectives. *Asia Pacific Education Review, 21*(1), 51–62.
Stevens, R. J., Madden, N. A., Slavin, R. E., & Farnish, A. M. (1987). Cooperative integrated reading and composition: Two field experiments. *Reading Research Quarterly, 22*(4), 433–454.
Sun, G., & Shen, J. (2014). Facilitating social collaboration in mobile cloud-based learning: A teamwork as a service (TaaS) approach. *IEEE Transactions on Learning Technologies, 7*(3), 207–220.
Terras, M. M., & Ramsay, J. (2012). The five central psychological challenges facing effective mobile learning. *British Journal of Educational Technology, 43*(5), 820–832.
Ting, Y. L. (2013). Using mobile technologies to create interwoven learning interactions: An intuitive design and its evaluation. *Computers & Education, 60*(1), 1–13.
Tsai, C. C. (2004). Beyond cognitive and metacognitive tools: The use of the Internet as an 'epistemological' tool for instruction. *British Journal of Educational Technology, 35*(5), 525–536.
Uzunboylu, H., Cavus, N., & Ercag, E. (2009). Using mobile learning to increase environmental awareness. *Computers & Education, 52*(2), 381–389.
Vygotsky, L. (1978). *Mind in society: The development of higher psychological process.* Cambridge, MA: Harvard University Press.
West, J. F. (1990). Educational collaboration in the restructuring of schools. *Journal of Educational and Psychological Consultation, 1*(1), 23–40.
Wu, W. H., Wu, Y. C. J., Chen, C. Y., Kao, H. Y., Lin, C. H., & Huang, S. H. (2012). Review of trends from mobile learning studies: A meta-analysis. *Computers & Education, 59*(2), 817–827.