Trends in digital game-based learning in the mobile era: a systematic review of journal publications from 2007 to 2016

Ching-Yi Chang and
Gwo-Jen Hwang*

Graduate Institute of Digital Learning and Education,
National Taiwan University of Science and Technology,
Taipei, Taiwan
Email: frinng.cyc@gmail.com
Email: gjhwang.academic@gmail.com
*Corresponding author

Abstract: The application of mobile learning and the use of game-based instructional strategies have been demonstrated as promoting students' learning performances and motivation. Over the past decade, many researchers and educators have integrated mobile technology and the features of gaming into their instructional designs; however, there has been little systematic review of the applications and trends in mobile technology-supported gaming. In the present study, related international journal publications from 2007 to 2016 were reviewed by searching the WOS database. The aim of this literature review was to highlight the research domain and issues of promoting game-based learning in future mobile technology. Based on this review, trends in mobile game-based learning are proposed from various aspects, such as the adoption of mobile technologies, gaming types, application domains, learning strategies, research issues, research methods, and participants. Accordingly, several suggestions are given for future studies.

Keywords: digital game-based learning; mobile learning; ubiquitous learning; mobile games; educational games; technology-enhanced learning; computer-assisted learning; mobile games; mobile apps; mobile devices.

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Biographical notes: Ching-Yi Chang is a MSN, RN, Supervisor at the Department of Nursing, Cheng Hsin General Hospital in Taiwan. Her research interests include mobile and ubiquitous learning, digital game-based learning and nursing education.

Gwo-Jen Hwang is currently a Chair Professor at the National Taiwan University of Science and Technology. His research interests include mobile and ubiquitous learning, digital game-based learning, adaptive learning, and artificial intelligence in education.

1 Introduction

Digital game-based learning (DGBL) refers to the learning approach that incorporates educational content or learning designs into digital games. It involves activities that could engage learners in simple tasks or complex problem-solving skills (Deubel, 2006). During the gaming process, learners learn how to overcome challenges and compete with classmates while solving well-designed simulation problems, a process which can increase learners' learning motivation, and in turn improve their learning achievement (Prensky, 2001). Owing to the rapid advancements in and popularity of mobile and wireless communication technologies, digital game-based learning has moved into the mobile era (Ciampa, 2014). Hwang et al. (2007) indicated that the development of wireless communication and sensors offers innovative thinking to researchers in the field of digital learning and education; therefore, they have started attempting to lead students to combine the knowledge in textbooks and real-life environments through the actionability of mobile technology. For example, Huizenga et al. (2009) used mobile games in the classroom, helping high school students to gain knowledge of the history of Amsterdam in the Middle Ages. Due to the advancements in digital technology and the popularity of the Internet, integrating them into game-based teaching has attracted attention (Hwang et al., 2012; Hwang et al., 2016; Hwang et al., 2013). At the same time, along with the development of mobile technology, many games can be played on phablets, and can even coordinate with locating systems, such as GPS (Global Positioning System) and QR codes (Chang and Lin, 2012; Riconscente, 2013).

Over the past decade, scholars have attempted to understand the application trend of game-based learning and mobile technology-supported learning in education by reviewing the literature in these areas. Regarding the use of mobile technologies in education, Klopfer and Squire (2008) examined the innovative applications of mobile technology for the purpose of education and entertainment, and discussed the instructional design and influences of the techniques. Hwang and Tsai (2011) reviewed six SSCI papers mainly related to mobile learning and ubiquitous learning. Wu et al. (2012) found that most of the research on mobile learning focused on its effects, and then secondly on the design of mobile learning systems; moreover, the experimental design method was the main research method. Hsu et al. (2012) surveyed the mobile and ubiquitous learning studies published from 2005 to 2009, and found that the amount of research in this field had significantly increased. Recently, Sung et al. (2016b) examined 110 experimental journal articles published from 1993 to 2013, and reported that, the use of mobile devices, such as tablet computers, PDAs (Personal Digital Assistants) and smartphones, had great potential in improving students' learning performances if effective learning approaches could be adopted. In the meantime, Chiang et al. (2016) investigated the patents of mobile learning between 1976 and 2013, analysing the patents from China Intellectual Property Right Net (CNIPR), the United States Patent and Trademark Office (USPTO) and Espacenet, which included nearly 90 countries.

On the other hand, several review studies of digital game-based learning have been conducted. For example, Hwang and Wu (2012) conducted a literature review on the publications in seven SSCI journals from 2001 to 2010. They indicated that the researchers paid close attention to students' motivation, perceptions of and attitudes toward digital games so as to understand the increasing trend of applying mobile technology in education. Martí-Parreño et al. (2016) reviewed 139 papers from well-

recognised journals from 2010 to 2014. They mentioned that games can increase students' inner learning motivation, and agreed with active learning based on every student's learning needs. Hung et al. (2016) analysed digital game-based language learning research published from 2010 to 2014, finding that multiplayer online role-play games were the most frequently mentioned games in the studies published in that period.

From those review studies of mobile learning and game-based learning, it is found that the studies in both fields have attracted much attention from researchers and educators; however, there have been few literature reviews on the application of mobile games in education. Therefore, this study intended to examine the trends of the papers on mobile technology-supported game-based learning published in international journals from 2007 to 2016, and the changes in mobile technology-supported game-based learning from the first 5-year period of 2007 to 2011 to the second period of 2012 to 2016. The research questions were proposed as follows:

1 Which were the top 10 countries and productive authors integrating mobile learning into the field of games from 2007 to 2016?

2 What were the major journals publishing mobile game-based learning studies from 2007 to 2016?

3 What were the major gaming types adopted in mobile game-based learning studies from 2007 to 2016?

4 What mobile devices were adopted in game-based learning studies from 2007 to 2016?

5 What were the learning strategies adopted in mobile game-based learning studies from 2007 to 2016?

6 What were the research methods adopted in mobile game-based learning from 2007 to 2016?

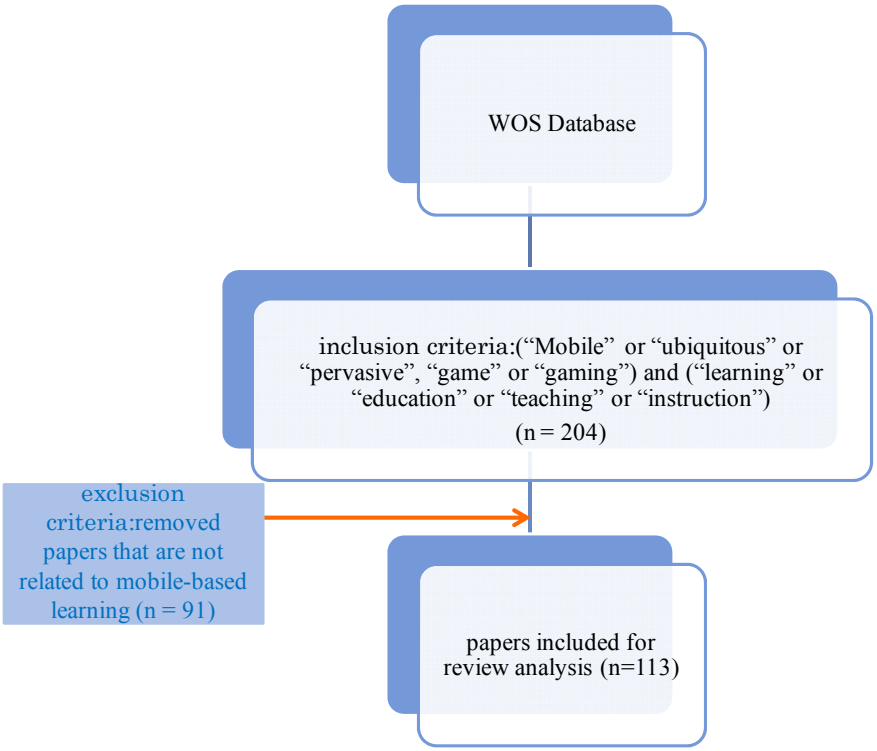
7 What were the participants of mobile game-based learning from 2007 to 2016?

2 Method

2.1 Data collection

The present study investigated papers from the Web of Science database from 2007 to 2016 by searching for the publications whose titles, abstracts, or keywords met the logical condition (*"Mobile" or "ubiquitous" or "pervasive"*) *and* (*"game" or "gaming"*) *and* (*"learning" or "education" or "teaching" or "instruction"*). A total of 204 papers published in SSCI/SCI journals were eligible for this study. Through manual filtering by two researches for one month, 113 papers were included in the present study by deleting 91 which were not related to mobile game-based learning (see Figure 1). To ensure the reliability of the filtering process, if any inconsistency between the filtering results was found, the two reviewers need to discuss until an agreement was reached.

Figure 1 WOS database searching steps



2.2 Data distribution

A total of 113 papers were included in this study. The papers were reviewed and categorised by three researchers based on the pre-defined coding scheme. If the coding result was not consistent, they would discuss until an agreement was reached.

Figure 2 illustrates the papers on the application of mobile learning in games published from 2007 to 2016. There were no literature reviews on mobile game-based learning in 2007; before 2011, no more than 10 papers on mobile learning applied in games were published each year. Since 2011, scholars have paid more attention to this field, with 31 papers published in 2015. The number of papers is thus increasing at an astonishing rate.

2.3 Coding schemes

In this study, the categories for analysing the target studies were determined by referring to the Technology-based Learning Review (TLR) model suggested by Hsu et al. (2012), who pointed out that, to investigate the trends in technology-based learning, several dimensions need to be taken into account, including "Research purposes," "Application domains," and "sample groups." They also suggested including the factors associating the three dimensions, that is "Research issues," "Research methods," and "adopted technologies/learning environments," as shown in Figure 3.

Figure 2 The number of papers published from 2007 to 2016 on mobile learning applying games

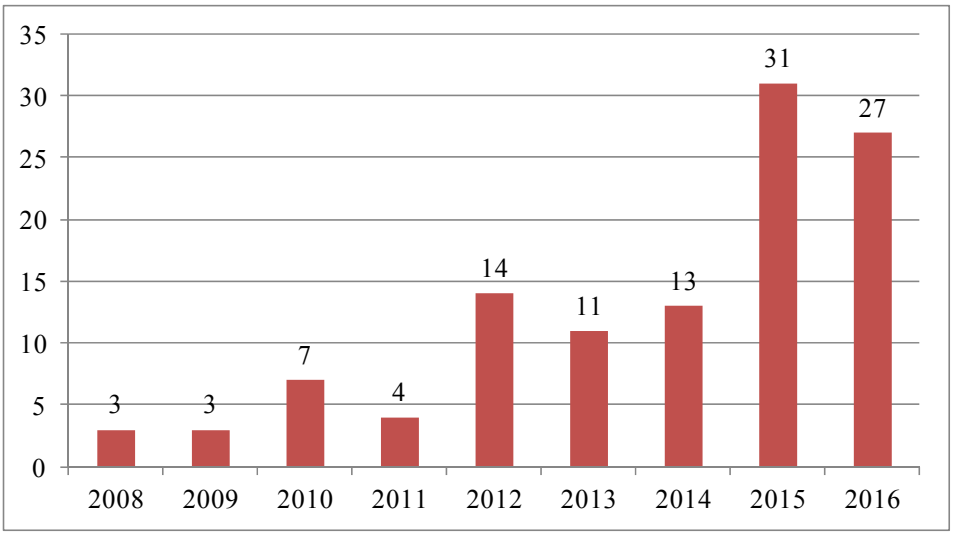
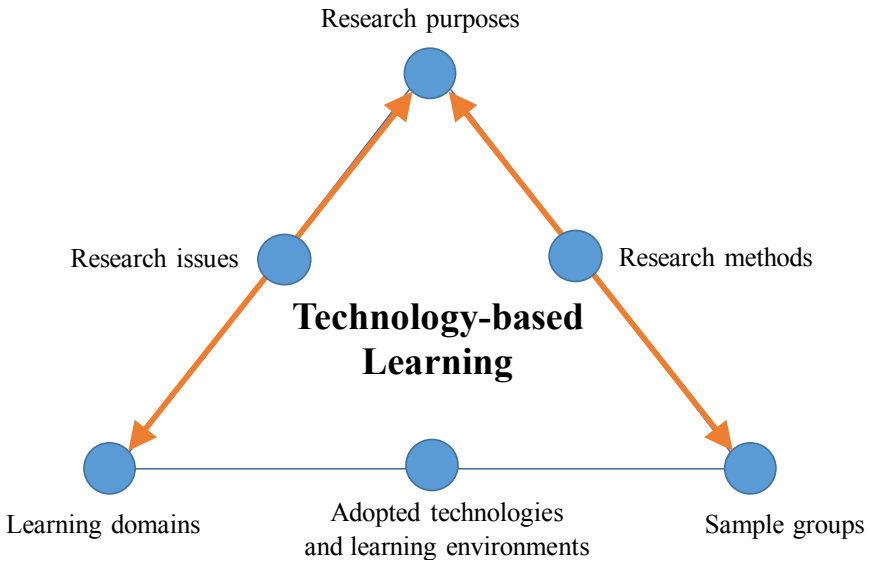


Figure 3 Technology-based learning model



In addition, we also referred to the classification and coding schemes devised by previous scholars to analyse the contents, including game types, types of mobile devices, subjects and modality, research methods, participants and research topics, and main activity locations (Hwang and Tsai, 2011; Hwang and Wu, 2012, 2014; Hwang et al., 2012). Accordingly, seven categories were adopted in this study, namely major research purposes, research methods, adopted mobile technologies, sample groups, research application domains, and research issues.

Descriptions of these classifications are presented in the following.

1 *Game types*

According to Prensky (2001), we classified games into eight categories based on the characteristics of the games and their content as follows: Simulation games, Role-playing games, Tutorial games, Puzzle games, Exergames, Board games, Hybrid genre, and Gamification.

2 *Mobile technologies adopted*

In the present study, we referred to the classification of mobile devices by Ozdamli and Uzunboylu (2015), dividing the devices in the reviewed papers into Wearable devices, Smartphones/apps for smart phones, Tablet computers, Notebooks, PDAs, Mixed, Robots, and no technology adopted.

3 *Subjects*

The coding of subjects and modality referred to Hsu et al. (2012), and included Engineering or computers, Science (Physics, Chemistry, Biology, Environmental Science, or Natural Science), Health, Medical or Nursing, Social science or social studies (e.g., local culture, history), Arts or design, Languages, Mathematics, Business and management, and no subject (i.e., review studies)

4 *Learning strategies*

In line with mobile learning strategies, we classified the learning strategies into 11 categories: Direct-guided learning, Inquiry-based learning, Contextual mobile learning, Collaborative learning, Mindtools, Thematic discussion, Peer assessment, Project-based learning, Contests, and Non-specified (i.e., reviews), as suggested by Lai and Hwang (2015). Table 1 provides descriptions of the 11 strategies.

5 *Research methods, participants, and topics*

In the current study, we also analysed the research methods, participants, and topics of each paper. The research methods and the measure adopted by researchers refer to the classification of educational research by Johnson and Christensen (2000). They divided research methods into the Experimental design method, Questionnaire surveys, the Qualitative research method, System development, Document analysis, and Mixed research methods.

In line with Wu et al. (2012), research participants were classified into Elementary school students, Junior and senior high school students, Higher education, Instructors, Working adults, Unintended audience (Non-specified), Others, Groups not discussed in the papers, and Non-specified.

According to the papers related to the design of the digital teaching materials, Maas et al. (2016) and van Merrienboer et al. (2002) proposed three domains of educational activities or learning: the Cognitive Domain, the Affective Domain, and the Psychomotor Domain. The Cognitive domain refers to learning knowledge, concepts, principles, their application, and the ability of problem-solving. The major characteristic of this domain is the acquisition and application of knowledge. The Affective Domain is the positive or negative psychological reaction to an external stimulus, such as like or disgust, which then influences the actions people take. The Psychomotor Domain indicates that physical movement is an acquired ability. Based on this, the results demonstrate the physical

movement in terms of speed, precision, strengths, or techniques in execution, for example, playing instruments, dancing, or playing basketball. In addition, apart from these issues discussed in previous research, this study also probed the cognitive domain, affective domain, psychomotor domain, interviews, and causal analysis.

Table 1 The classification and description of learning strategies in this study

Learning strategy	*Description*
Direct-guided learning	Assist students with data collection, collation, or testing through expansive learning materials, websites, or software provided by mobile devices
Peer assessment	Guide students to evaluate and comment on peers' performance or work according to the scoring rubrics offered by the instructors. In the activity, students are not only learners/reviewees, but also teachers/reviewers
Collaborative learning	Instruct students to engage in real-time interaction through mobile technology, including discussion, sharing, and mutual problem-solving
Thematic discussion	Guide students to collect data and discuss online based on the assigned topics
Mindtools	Instruct students to make use of Mindtools to generalise, integrate, conceptually connect, or reason out the knowledge
Project-based learning	Guide students to accomplish the project based on the assigned topics, including reports or any kind of work
Inquiry-based learning	Instruct students to discover the questions, find out the solutions to the questions, and organise the knowledge on their own
Contextual mobile learning	Guide students to bring knowledge outside the classroom to apply, observe, collect data, solve problems, and discuss
Contests	Integrate the strategies of game competition into mobile learning
Non-specified	No learning strategy was adopted in some reviewed papers

6 *Main activity locations*

The function and convenience of mobile technology has a significant influence on the application of mobile technology-supported game-based learning. In the period from 2007 to 2016, mobile technology changed significantly. Conforming to the devices and activity locations used in the reviewed papers, for the coding of subjects and modality, we referred to Hsu et al. (2012), classifying the location of the mobile technology-supported game-based learning as: Classroom or laboratory, School campus, Museum, Library or historical building, Ecological area, Zoo or garden, Science park, and Non-specified.

3 Results

3.1 Nationality, authors and journals

In the present study, we only considered the nationality of the first author of the papers on mobile technology applied in the field of games (see Figure 4). The results showed that many countries have already tried applying mobile technology-supported game-based learning in teaching. The top three countries are the USA (62 papers), Taiwan (34 papers) and England (31 papers).

We further analysed the authors who published more than two papers on mobile technology applied in the field of games from 2007 to 2016 (see Figure 5). The analysis only involved the first author of each paper. Among all the authors, B. Schmitz and T.H. Laine published the most papers (three papers each).

Figure 4 The top 10 countries integrating mobile learning into the field of games from 2007 to 2016

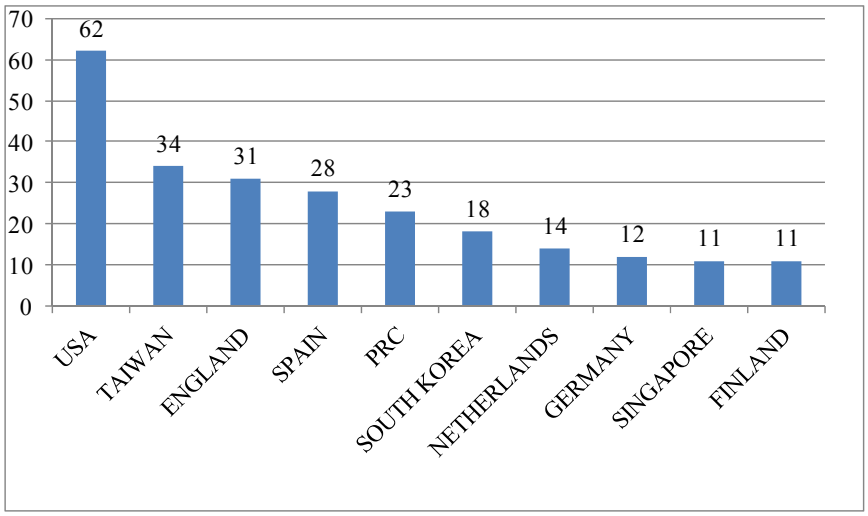
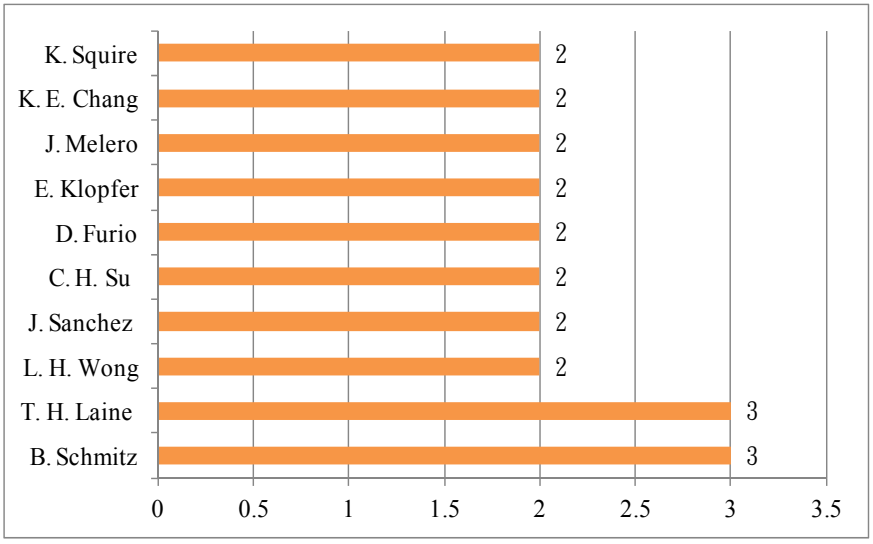
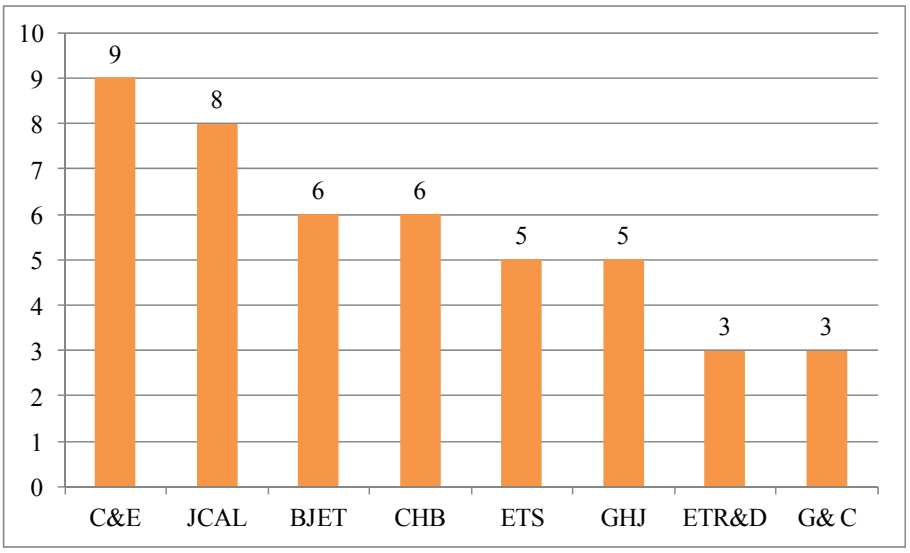


Figure 5 The research productivity of authors on mobile technology applied in games from 2007 to 2016



The journals which published more than two papers are: *Computers & Education* (*C&E*), the *Journal of Computer Assisted Learning* (*JCAL*), *the British Journal of Educational Technology* (*BJET*), *Computers in Human Behavior (CHB), Educational Technology & Society* (*ETS*), *Games for Health Journal* (*GHJ*), *Educational Technology Research and Development* (*ETR&D*), *and Games and Culture* (*G&C*) (see Figure 6). The top three international journals with the highest productivity in this area are *Computers & Education* (*C&E*) with nine papers, the *Journal of Computer Assisted Learning* (*JCAL*) with eight papers, and the British *Journal of Educational Technology* (*BJET*) with seven papers.

Figure 6 Number of articles on mobile learning published in international journals from 2007 to 2016



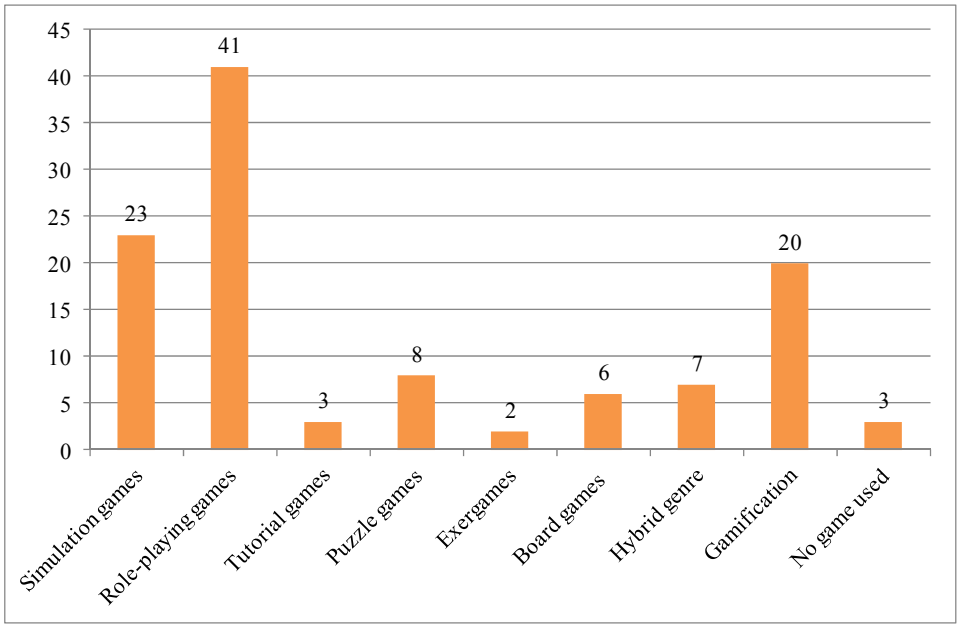
The statistical results of the authors and journal titles could be a good reference to those who intend to publish mobile game-based learning studies or host relevant workshops or conferences in the future.

3.2 Game types

Figure 7 illustrates the number of papers making use of mobile learning by game type from 2007 to 2016. The largest number of papers adopted role-playing games, with a total of 41; the next place is Simulation games with 23 papers, and then Gamification with 20 papers. For example, Klopfer et al. (2012) investigated how students used an educational game to learn the knowledge of "weather." Twenty students claimed that they had more interest in understanding academic topics on the weather and climate after they participated in the game. Furio et al. (2013) proposed that children should strengthen their cognition of the water cycle. Their study compared the use of iPhones and tablet computers when children played an educational game about the water cycle. The game

consisted of different ways of interaction to obtain the best gamification, for example, touch screen and accelerator, combining AR with a mini game versus a non-AR mini game.

Figure 7 The number of papers implementing mobile learning by game type from 2007 to 2016



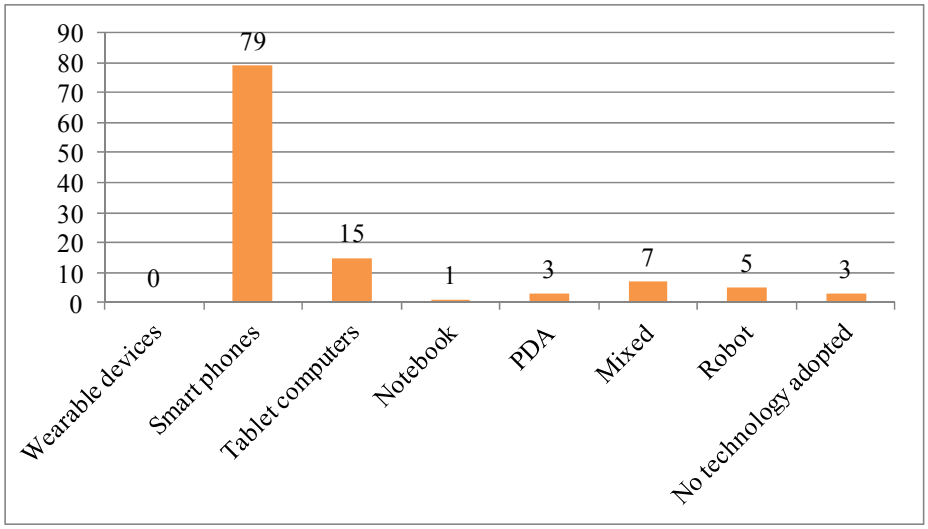
In addition, in the 113 reviewed papers, the researchers discovered that the types of game console changed remarkably as time went by, and the environment also altered. Huizenga et al. (2009) made use of role-playing games in teaching to assist junior high school students to play a mobile city game. The researchers investigated students' motivation to learn about the Middle Ages and to acquire general knowledge during the game. More recently, Arachchilage et al. (2016) developed a role-playing game that could be used as an educational tool to help users protect themselves from phishing and found that it increased the avoidance behaviour of users. Based on the statistical results reported in Figure 7, it is suggested that, for those new researchers who intend to adopt the mobile gaming approach, the three most frequently adopted game types (i.e., simulation game, role-play game and gamification) can be considered first.

3.3 Mobile technologies adopted

The function and convenience of mobile technology has a significant influence on the application of mobile technology-supported game-based learning. From 2007 to 2016, mobile technology changed significantly. Figure 8 demonstrates the distribution of mobile devices in 113 papers. The most commonly used devices are smartphones/ apps with 79 papers, followed by Tablet computers with 15 papers. In terms of papers using apps for smartphones, Chen and Tsai (2015) engaged learners in playing two

digital games using Mobile Eye eye-tracking to record their eye movement, and then examined the patterns of eye-hand coordination, which provided a good reference to the design and improvement of digital games.

Figure 8 The number of papers on game-based learning by mobile device used from 2007 to 2016



We divided the 113 papers into two categories: from 2007 to 2011 and from 2012 to 2016, and examined the situation of mobile device use in these two periods (see Table 2). The main mobile device used during both periods was smartphones/apps for smartphones (showing a 13% increase). This development may have a lot of do with the popularity of mobile devices and wireless networks.

Table 2 The percentage of mobile device use in the field of game-based learning from 2007 to 2011 and from 2012 to 2016

Mobile devices	*Total number*	*The percentage from 2007 to 2011 (quantity/total numbers in the first five years*100%)*	*The percentage from 2012 to 2016 (quantity/total numbers in the second five years *100%)*	*Percentage of increase*
Wearable devices	0	0%	0%	0%
Smartphones/apps for smartphones	79	59%	72%	13%
Tablet computers	15	6%	15%	9%
Notebook	1	0%	1%	1%
PDA	3	12%	1%	–11%
Mixed	7	0%	7%	7%
Robot	5	18%	2%	–16%
No technology adopted	3	6%	2%	–4%

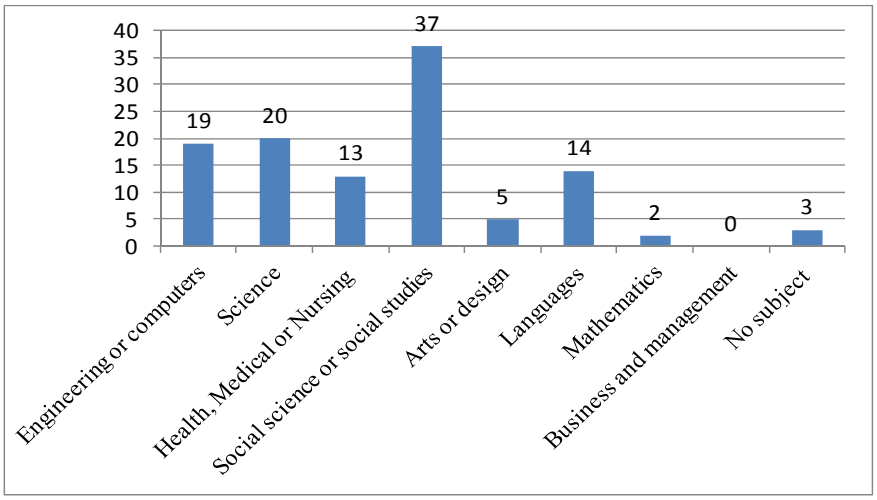
In the research on mobile technology involved in game-based learning from 2007 to 2011, DeShazo et al. (2010) investigated mobile phone video games designed to deliver diabetes education. With regard to iconic research on mobile technology involved in game-based learning from 2012 to 2016, Ojanen et al. (2015) presented GraphoGame (GG), a technology-based intervention method for supporting children with reading difficulties. The research demonstrated that the mobile game was helpful to children in solving the problem of differentiating speech sounds in reading. In addition, the game was able to raise instructors' awareness of developing reading skills and effective reading instruction methods. Sung et al. (2016a) proposed a problem-solving strategy for supporting collaborative mobile learning activities, and a mobile learning environment was developed. Based on a problem-solving strategy as a mobile learning method, the results improved students' learning performance, and promoted group learning self-efficacy.

To sum up, according to 113 reviewed papers related to mobile technology-supported game-based learning from the WOS database on January 2017, the use of such mobile devices as smartphones, PDAs, and tablet computers, and the innovative teaching of ubiquitous learning are already being studied. On the other hand, there were no articles investigating the application of Bluetooth, Infrared rays, or the Internet of Things in game-based education, and more specifically, no papers incorporating Bluetooth, Infrared rays, or the Internet of Things in combination with flow experience.

3.4 Applied subjects

Figure 9 shows the subjects in which mobile technology-supported game-based learning was applied from 2007 to 2016. There were 37 articles for Social science or Social studies, and 20 articles for Science (Physics, Chemistry, Biology, Environmental Science or Natural Science). On the other hand, among all the subjects to which mobile technology-supported game-based learning was applied from 2007 to 2016, Art or Design, Mathematics, and Business and Management were seldom mentioned and are thus worth exploring in the future.

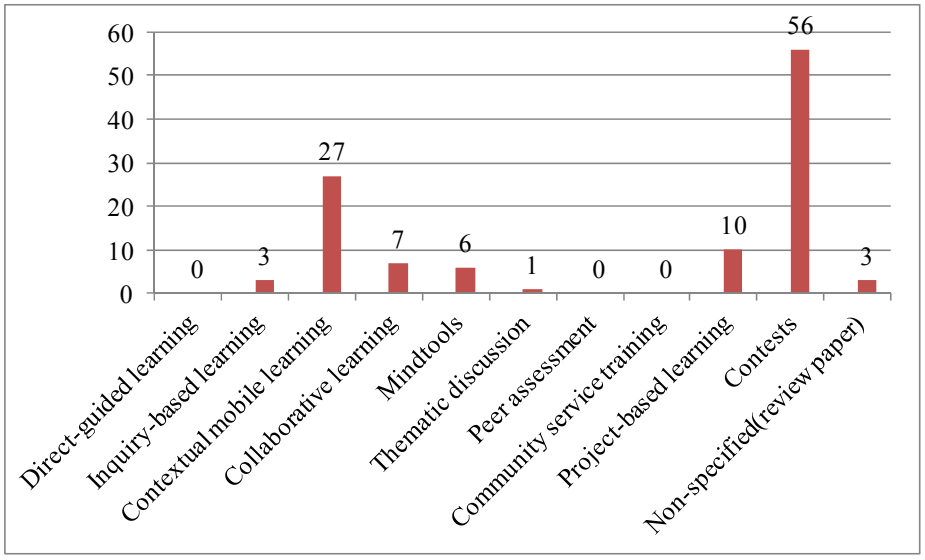
Figure 9 The subjects in which mobile technology-supported game-based learning were applied from 2007 to 2016



3.5 Learning strategies

The distribution of learning strategies applied in mobile technology-supported game-based learning from 2007 to 2016 is shown in Figure 10. There were 56 papers involving Contests, followed by Contextual mobile learning with 27 papers. As an example of applying contests, Kose et al. (2015) implemented digital games for sign language aided by humanoid robots, designed specifically for children who had barriers to communicate with people.

Figure 10 The distribution of learning strategies applied in mobile technology-supported game-based learning from 2007 to 2016



We then divided the 113 papers into two categories: from 2007 to 2011 and from 2012 to 2016, and examined the situation of learning strategies (see Table 3). The main strategy adopted during these two periods is Contests (with a 24% increase). This reconfirmed that the development may have a lot of do with the popularity of mobile devices and wireless networks. To give an example of Contests as the learning strategy, Chuang and Huang (2015) analysed three commercial games of three different game genres (action, puzzle, and role-play) rated by 32 student raters and four expert raters. The study examined their construct validity, internal consistency reliability, and interrater reliability as a guideline for digital game story designers and product developers to modify creative and entertaining game stories. In terms of Contextual mobile learning, Hwang and Chang (2016) presented a location-aware mobile learning way using the contest strategy to conduct local culture activities in social studies class. The findings showed that this measure largely enhanced students' local culture identity, learning interest, and learning attitude, and that it also decreased students' cognitive load.

Table 3 The application of learning strategies in games from 2007 to 2011 and 2012 to 2016

Learning strategy	*Total number*	*The percentage from 2007 to 2011 (quantity/total numbers in the first five years*100%)*	*The percentage from 2012 to 2016 (quantity/total numbers in the first five years*100%)*	*Percentage of increase*
Direct-guided learning	0	0%	0%	0%
Inquiry-based learning	3	6%	2%	–4%
Contextual mobile learning	27	29%	23%	–6%
Collaborative learning	7	6%	6%	0%
Mindtools	6	6%	5%	–1%
Thematic discussion	1	0%	1%	1%
Peer assessment	0	0%	0%	0%
Project-based learning	10	18%	7%	–11%
Contests	56	29%	53%	24%
Non-specified (review paper)	3	6%	2%	–4%

3.6 Research methods

In the current study, we not only analysed the 113 papers for their age, applied subject, applied strategy, and mobile devices, but also investigated the research methods, participants, and research topics in each article, for example, the Experimental design method, Questionnaire survey, the Qualitative research method, System development or Document analysis. As shown in Figure 11 and Table 4, among all 113 papers, there were 50 adopting the Experimental design method, which refers to involving participants in system or learning strategies, and then examining the effects of the intervention on the participants. A total of 27 papers were categorised into the research method of System development, which developed a game platform and then verified its effects. Another 16 papers adopted mixed research methods, for example, the effects of the combination of the Experimental design method and the Qualitative research method, the effects of integrating the Experimental design method and System development. There were 13 papers classified into the Qualitative research method, which is similar to Questionnaire surveys, and includes interviews of focus groups, case studies, and so on. Another three papers were classified into Document analysis; four papers adopted the method of Questionnaire survey, which investigated participants' preference for pervasive tools or the implementation of technology in games.

In term of experimental design method, Su and Cheng (2015) developed a series of gamified learning activities based on a Mobile Gamification Learning System and implemented those in the science class of an elementary school. Through a situation-aware mobile learning environment, they investigated how science learning, achievement, and motivation were influenced by the gamified learning approach, and explained the effects on motivation and students' learning. The results indicated that the students focused on the outdoor learning activities by using smartphones. Incorporating mobile and gamification technology into a botanical learning process could gain better learning achievement and a higher level of learning motivation.

Figure 11 The percentage of each research method used from 2007 to 2016

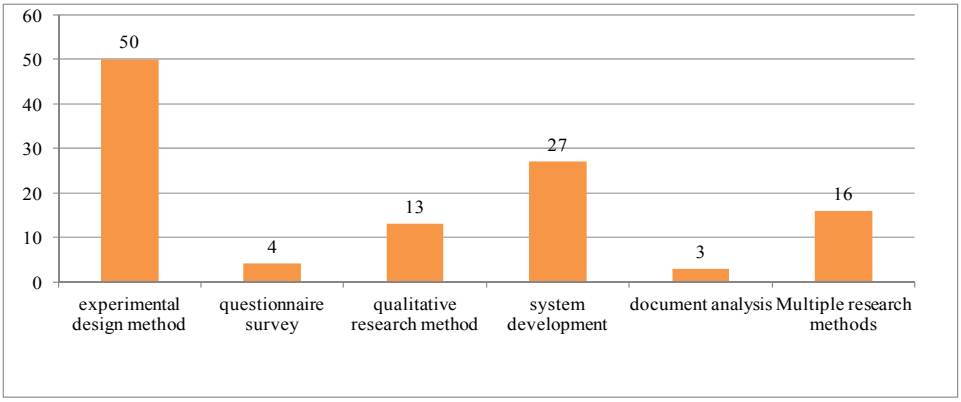


Table 4 The percentage of research methods applied with mobile technology-supported game-based learning from 2007 to 2011 and 2012 to 2016

Research methods	*Total number*	*The percentage from 2007 to 2011 (quantity/total numbers in the first five years*100%)*	*The percentage from 2012 to 2016 (quantity/total numbers in the first five years*100%)*	*Percentage of increase*
Experimental design method	50	41%	45%	4%
Questionnaire survey	4	0%	4%	4%
Qualitative research method	13	12%	11%	–1%
System development	27	29%	23%	–6%
Document analysis	3	6%	2%	–4%
Mixed research methods	16	12%	15%	3%

In term of qualitative research method, Su and Hsaio (2015) assisted instructors in evaluating mobile learning educational games by proposing the Multiple Criteria Decision Model based on flow theory and designing a flow dimension evaluation guideline. They then invited experts to evaluate several educational games based on the guideline.

In term of questionnaire survey, Chang and Lin (2012) developed the strategies of inquiry and games on smartphones based on the game-based inquiry learning theory. A questionnaire analysis was carried out after the activity. The findings indicated that interactive learning increased learning motivation and interest.

Table 4 shows the research methods that were adopted in papers during the periods of 2007 to 2011 and 2012 to 2016. As depicted in Table 4, Questionnaire survey and Experimental design method are the two crucial research methods during these two periods (with a 4% increase for each). These are followed by Mixed research methods (with a 3% increase). According to this table, the researchers also put more emphasis on System development as the research method in mobile technology-supported game-based learning in these two periods (29% and 23% respectively).

3.7 Research topics

Table 5 depicts the percentage of each research topic discussed in the papers. A combination of two or more research topics increased the most in these two periods (with a 14% increase). The next place is the research topic of Self-efficacy/confidence/ performance expectations (with a 5% increase). However, there was little research on Higher-order thinking and Learning style or on students' Critical thinking, Creativity, or Problem-solving in mobile technology-supported game-based learning from 2012 to 2016. There were 80 papers investigating two or more topics, indicating that the researchers tried to investigate the impacts of applying mobile technology in game-based learning from various perspectives. As for Cooperation and communication, several studies (with a 2% increase in the second-time period) reported that mobile game-based learning had a positive effect, showing another potential of this approach (Laine and Suk, 2016; Seok and DaCosta, 2015).

Table 5 The percentage of each research topic discussed in papers from 2007 to 2011 and 2012 to 2016

Research topics	*Total number*	*The percentage from 2007 to 2011 (quantity/total numbers in the first five years*100%)*	*The percentage from 2012 to 2016 (quantity/total numbers in the first five years*100%)*	*Percentage of increase*
Acceptance of technology	0	0%	0%	0%
Attitude/motivation/ effort expectations	3	0%	3%	3%
Self-efficacy/ confidence/ performance expectations	5	0%	5%	5%
Satisfaction/interest	5	12%	3%	–9%
Learning achievement/ performance (cognitive)	3	0%	3%	3%
Learning achievement/ performance (skill)	4	12%	2%	–10%
Learning behaviour	3	0%	3%	3%
Learner opinion/learning experience	3	0%	3%	3%
Influence relationship or causal analysis	1	12%	0%	–12%
High-order thinking	0	0%	0%	0%
Cooperation and communication	2	0%	2%	2%

Table 5 The percentage of each research topic discussed in papers from 2007 to 2011 and 2012 to 2016 (continued)

Research topics	*Total number*	*The percentage from 2007 to 2011 (quantity/total numbers in the first five years*100%)*	*The percentage from 2012 to 2016 (quantity/total numbers in the first five years*100%)*	*Percentage of increase*
Learning style	0	0%	0%	0%
Mix two or more	80	59%	73%	14%
Non-specified (review paper)	3	6%	2%	–4%

As shown in Table 6, the majority of participants in the research from 2007 to 2011 were adults (35%), while the largest group of subjects from 2012 to 2016 was elementary school students (26%), with teachers in second place (18%). For example, Chen et al. (2016) adopted an integrated gaming and multistage guiding approach to develop a mobile game for elementary school natural science course. The experimental results showed that both the gaming and multistage guiding mechanism enhanced students' learning achievements in the mobile learning context. They concluded that positive help could be provided through involving mobile technology in game-based learning. As an example of other research participants, Maas et al. (2016) designed an educational diabetes digital board game centred on patients with diabetes.

Table 6 The distribution of research participants in mobile technology-supported game-based learning from 2007 to 2011 and 2012 to 2016

Research participants	*Total number*	*The percentage from 2007 to 2011*	*The percentage from 2012 to 2016*	*Percentage of increase*
Elementary school students	27	12%	26%	14%
Junior and senior high school students	6	12%	4%	–8%
Higher education	14	6%	14%	8%
Teachers	19	12%	18%	6%
Working adults	15	12%	14%	2%
Adults	12	35%	6%	–29%
Other	2	0%	2%	2%
None	10	12%	8%	–4%
Non-specified	8	0%	8%	8%

On the other hand, several studies did not have specific participants; for example, Chittaro (2016) applied serious games in aviation safety education; the learners could be adults, students or children. They reported that serious games were more effective than the traditional learning methods in terms of changing learners' safety-related perceptions.

Finally, regarding other research topics, the study examined the influence level of main activity locations in mobile technology-supported game-based learning (see Table 7). The most common research location during 2007 to 2011 and 2012 to 2016 was the Classroom or laboratory (10%). In addition, school campus, museums or even other science environments are also the possible locations for design mobile technology-

supported game-based learning activities. Moreover, research of non-specified locations in mobile technology-supported game-based learning decreased by 5%, which illustrates the trends of applying mobile games to the learning activities conducted in specified real-world contexts.

Table 7 The percentage of activity locations for mobile technology-supported game-based learning from 2007 to 2011 and 2012 to 2016

Main activity locations	*Total number*	*The percentage from 2007 to 2011*	*The percentage from 2012 to 2016*	*Percentage of increase*
Classroom or laboratory	83	65%	75%	10%
School campus	1	6%	0%	–6%
Museum, Library or historical building	6	6%	5%	–1%
Ecological area, zoo or garden	1	0%	1%	1%
Science park	7	6%	6%	0%
Non-specified	15	18%	13%	–5%

4 Discussion

Mobile learning has become a global phenomenon. Digital learning and smartphones normally coexist, and it is common for game-based learning to involve multiple phenomena. The popularity of the Internet and game-based learning has increased rapidly; therefore, the incorporation of mobile learning into games has been gradually increasing in teaching (Hwang and Wu, 2014). To understand the current situation of mobile learning in teaching for the development and promotion of future studies, the present study adopted Document Analysis to review the situation of games applying mobile technology from 2007 to 2016, with an emphasis on research methods, research topics, and research tools. Based on the findings, the concept of applying the development and design of games to mobile learning has become an essential trend. Combining mobile technology and providing appropriate learning strategies has huge potential to improve education and students' learning effects.

As shown in the results of research methods, topics, and participants, mobile learning technology can enhance students' learning achievement, motivation and attitudes (Chen et al., 2014; Furio et al., 2015; Kondo et al., 2012). On the other hand, in the digital game-based learning contexts, it is easier for students to understand the crucial concepts of the subjects, feel much happier and more interested in learning. Thus, many researchers have not only focused on system development, but have also put more emphasis on learners' needs and perceptions regarding mobile learning (Chittaro, 2016; Hamari et al., 2016; Hwang et al., 2016). Consequently, the number of mobile gaming studies is increasing in a rapid pace.

In addition, the statistics depict that there are still plenty of dimensions to investigate in the future, for example, there are many types of educational games that can be integrated in practice, including console games, handheld games, arcade games, computer games, mobile games, puzzles, simulations, and sports games. Most of the educational applications only support single-person use, such as the one developed

by Leinonen et al. (2016). Therefore, educational games incorporating multiplayer interactive simulation could also be a potential direction for future studies.

Moreover, it is found that most authors have attempted to adopt new technologies (e.g., AR) in mobile gaming studies for both formal and informal school education. However, there are still numerous learning strategies which have not been extensively used. Hwang and Wu (2014) pointed out the importance of developing or applying effective strategies to enhance students' learning achievements and mobile learning. Mobile learning technology is an important vehicle based on problem-based learning guidance. Whether appropriate learning strategies or mobile learning tools are provided during the learning process is the key factor to improving students' performance. In terms of learners, in addition to the possible target users such as school students and in-service staff, combining proper learning strategies or technologies is worthy of investigation, for example direct-guided learning, inquiry-based learning, contextual mobile learning, collaborative learning, Mindtools, thematic discussion, peer assessment, community-based practice, project-based learning, contests, video sharing, and so on.

In term of application domains, it is found that no study was related to "Business and Management," which is surprising since "contexts," "events" and "decision-making" are important elements in this domain. On the other hand, from the aspect of learning strategies, it is found that "peer assessment" and "direct-guided learning" were not adopted in the mobile gaming studies. This could be due to the fact that most researchers of mobile gaming are of computer science background. Therefore, in the future, it is suggested that researchers from different fields (i.e., computer science, management, and education) can cooperate in developing mobile gaming studies.

5 Conclusions

The main purpose and contribution of the present study is that the ways people learn are increasingly varied because of the rapid development of technology. Via using mobile technology and network communication, learning guidance and supports can be provided without being limited by time and space, implying that more learning opportunities and resources can be offered to facilitate learning. Moreover, more effective teaching models can be developed by taking the offering of instant and personalised feedback on students' reflection and psychological support into account. In terms of the integration of mobile learning and game-based learning, good gaming or gamification models and learning strategies could be the crucial factor affecting students' learning achievement. Therefore, future studies could focus more on how to develop mobile game-based learning strategies and models which are more diverse, educational, and appropriate for all ages after examining the learning strategies adopted in the existing digital game-based learning and mobile learning studies.

Based on the results of the present study, we concluded that mobile game-based learning has been well recognised as an important research field. With the popularity of mobile and multimedia technologies, it can be foreseen that more studies and applications will be conducted in the coming years. Several suggestions for future studies on digital game-based learning are given as follows:

1 A better mobile learning mode could be provided for digital game-based learning by taking learners' personal factors, such as learning achievement or learning styles, into account.

2 It is suggested that, for those studies conducting digital game-based learning activities, employing both quantitative and qualitative methods could be an appropriate approach to providing convincing evidence with in-depth discussion.

3 Regarding the selection of learning devices for digital game-based supported mobile learning, smartphones and tablet computers are apparently the best choices nowadays. For future studies, the use of emergent technologies, such as wearable devices and sensing technologies, could benefit learners more in certain digital game-based supported mobile learning applications.

4 The participants of most digital game-based supported mobile learning studies were students and school teachers. It would be an interesting issue to investigate how digital game-based supported mobile learning facilities can benefit working adults.

5 It could be important to investigate why few or no digital game-based mobile learning studies were conducted for the health, medical, physical education, mathematics, language, engineering, and business domains.

6 It is suggested that researchers can pay more attention to the issues of learning behaviours, skills, and causal analysis in digital game-based mobile learning. In addition, learners' higher order thinking and collaboration tendencies or performance as well as their self-efficacy and learning anxiety are potential research issues of digital game-based associated mobile learning.

On the other hand, there are certain limitations to the present study which should be noted. First, the literature reviewed in this study was limited to journal articles indexed in the WOS database published from 2007 to 2016; therefore, the findings might not be able to represent all research trends in the field. Second, the categorising criteria (i.e., the technology-based learning model) and the coding schemes also imply certain limitations; that is, the aspects of the studies are significantly affected by the selected categorising model and the coding scheme.

To sum up, all types of digital game-based learning play important roles in education. In the mobile era, the role of game-based learning is becoming increasingly important for both formal and informal learning. Reviewing the literature and investigating the research trends as well as finding the current application status of digital game-based learning is helpful to researchers and educators for finding new research directions, designing effective learning activities, and providing better service. The findings of the present study can serve as a reference for all types of digital game-based supported mobile learning, supplements of past research, and important indicators for future mobile learning research. It is expected that, via knowing what has been done and what needs to be done in the future, better personalised service can be provided to satisfy learners' individual needs, and hence to create a friendly digital game-based environment.

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