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Applications, impacts and trends of mobile technology-enhanced learning: a review of 2008–2012 publications in selected SSCI journals

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Abstract: The use of mobile technologies in learning has attracted much attention from researchers and educators in the past decade. However, the impacts of mobile learning on students' learning performance are still unclear. In particular, some schoolteachers still doubt the effectiveness of using such new technologies in school settings. In this study, a survey has been conducted by reviewing the 2008–2012 publications in seven well-recognised Social Science Citation Index (SSCI) journals of technology-enhanced learning to investigate the applications and impacts of mobile technology-enhanced learning. It is found that mobile learning is promising in improving students' learning achievements, motivations and interests. In addition, from the survey, it is found that smartphones and tablet PCs have gradually become widely adopted mobile learning devices in recent years, which could affect the adoption of sensing technologies in the future. Accordingly, several open issues of mobile learning are addressed.

Keywords: mobile learning; ubiquitous learning; seamless learning; technology-enhanced learning; research trend; research issues.

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1 Background and objectives

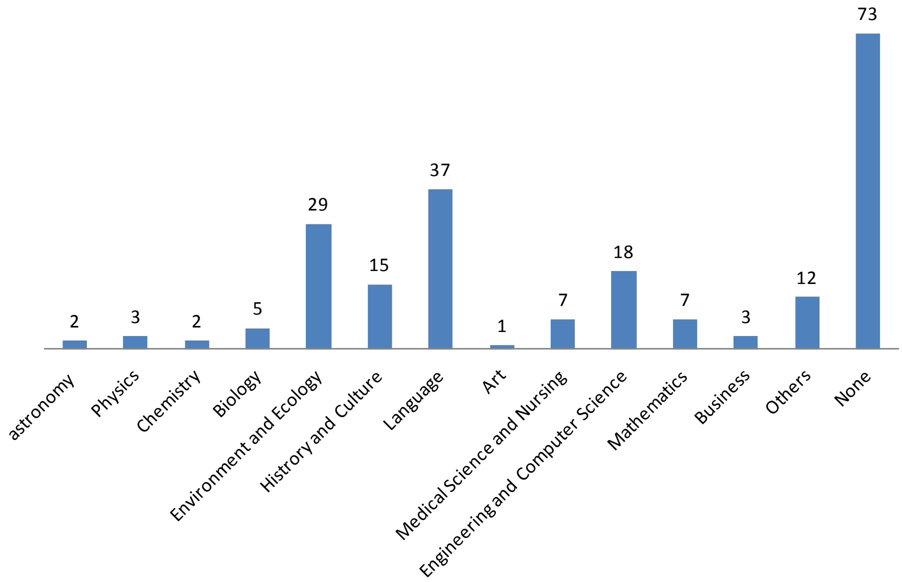
Although many studies have demonstrated the benefits of learning with digital resources or tools (e.g. Chen and Chen, 2009; Hsu et al., 2010; Yeh et al., 2010), educators have emphasised the necessity of 'authentic learning activities' in which students can work with problems from the real world (Brown et al., 1989; Tsai and Hwang, 2013). Researchers have further indicated the importance of placing students in a series of designed lessons that combine both real and virtual learning environments (Hwang et al., 2008; Wong and Looi, 2011; Wu et al., 2013). The popularity of wireless communication and mobile technologies has offered an opportunity to achieve such an objective (Lan and Huang, 2012; Chen et al., 2012). In this new learning environment, students are able to access digital resources and interact with learning systems via handheld devices and wireless networks when they are situated in real-world contexts (Wu et al., 2012a; Yin et al., 2013). Such a learning scenario has been called mobile learning, which refers to "learning that happens without being limited at a fixed location" or "learning that takes advantage of mobile technologies" (Sharples, 2000; Sharples et al., 2009; Sharples et al., 2002). Hwang et al. (2008) further summarised the characteristics of in-field learning with mobile, wireless and sensing technologies and proposed several "context-aware ubiquitous learning models".

Several studies have reported that applications of mobile learning have been significantly increased since 2008 (Hwang and Tsai, 2011; Tsai and Hwang, 2013). In the meantime, a survey reported by the International Telecommunication Union (ITU, 2012) has further revealed the potential of applying mobile technologies in educational settings in the coming years. Therefore, in this study, a survey of the applications and impacts of mobile learning has been conducted by reviewing the 2008–2012 publications in seven well-recognised journals, including *Computers & Education*, *Educational Technology & Society*, *Educational Technology Research and Development*, *Innovations in Education and Teaching International*, *British Journal of Educational Technology*, *Journal of Computer Assisted Learning* and *Interactive Learning Environments*. Those journals are selected since they mainly focus on publishing papers related to technology-enhanced-learning studies and have been included in Social Science Citation Index for ten years or more. The aim of this study was to investigate the potential applications and impacts of mobile learning. In addition, several open issues are also addressed.

2 Applications of mobile learning

The publications were read and categorised by two researchers with more than five years' experience of conducting mobile and ubiquitous learning studies. Among the 2674 publications in the selected journals from 2008 to 2012, 214 in total are related to the use of mobile technologies in educational applications. Figure 1 shows their distribution. It was found that the top four applications were language learning (37/214), environmental and ecological education (29/214), engineering and computer education (18/214) and historical and cultural education (18/214). Such a finding is reasonable since students need to be situated in an environment that enables 'any time' and 'anywhere' practicing to learn a language well. The use of mobile technologies does provide such learning facilities that meet the requirements of language learning.

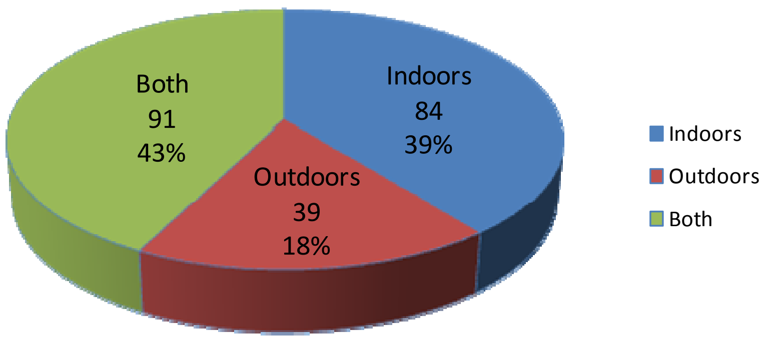
Figure 1 Applications of mobile learning in 2008–2012 (see online version for colours)



In addition, it is interesting to find that 73 studies were not relevant to a specific subject; instead, they mainly focused on investigating students' or teachers' perceptions of using mobile technologies. For example, the study presented by Chen (2010) mainly focuses on the development of a mobile assessment participation system for facilitating self- and peer-assessment in classrooms, while the study of Looi et al. (2010) aims to propose a research agenda and discuss methodological issues related to bridging formal and informal learning via reviewing mobile learning studies.

Figure 2 shows the contexts of mobile learning, including indoor and outdoor activities. It is found that 39% of the applications were conducted indoors, 18% were conducted outdoors and 43% consisted of both indoor and outdoor activities. For example, Hwang et al. (2012a) proposed an interactive concept map-oriented approach for supporting mobile learning activities in a butterfly ecology garden. In the meantime, Huang et al. (2012b) conducted an indoor mobile learning activity for an English course. Huang et al. (2012a) further showed the effectiveness of employing procedural scaffoldings to foster students' group interaction levels and learning outcomes in an indoor mobile learning activity. Recently, the study reported by Yang et al. (2013) showed that the use of mobile devices as a learning support for reading printed textbooks in indoor activities could significantly benefit students by leading to effective learning strategies or tools, such as concept mapping. On the other hand, the number of applications related to using mobile technologies to support both indoor and outdoor learning is increasing in the past five years. For example, Ogata et al. (2008) presented a mobile learning system with ubiquitous computing technologies to support both indoor and outdoor learning activities. It is inferred that, owing to the popularity of mobile devices, the conception of seamless or ubiquitous learning that refers to learning anywhere and at any time will gradually become a major trend of mobile learning, as indicated by Wong and Looi (2011).

Figure 2 Environments of mobile learning applications in 2008–2012 (see online version for colours)

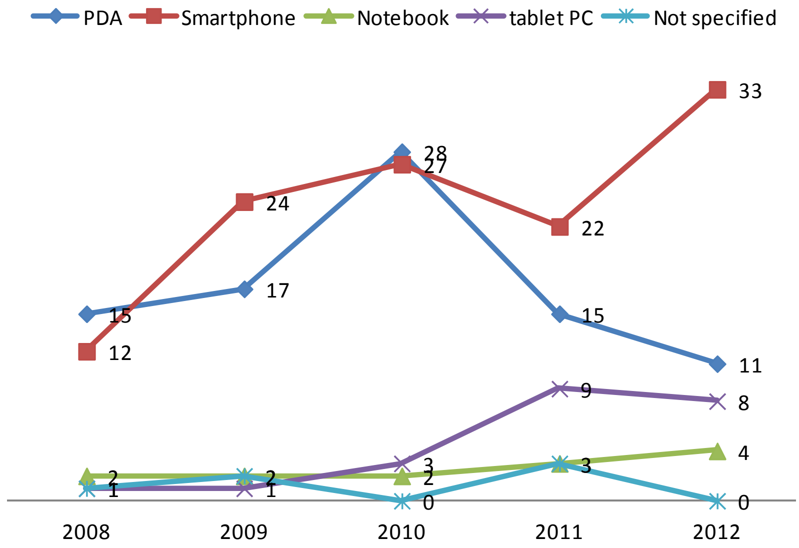


It is also interesting to find that the students in 59 out of the 214 cases (i.e. 28%) learned in groups; that is, the collaborative mobile learning activities were conducted in these applications. This finding reveals the fact that collaborative learning is no longer a rarely seen strategy of conducting mobile learning activities. Instead, it has been widely applied to various learning activities that encourage students to interact and collaborate with peers in the field trip. Furthermore, the effectiveness of collaborative mobile learning has been reported by several researchers. For example, Hwang et al. (2011a) conducted a concept map-based collaborative mobile learning activity in the field and found that the students had better leaning performance than those who learned with the concept map-based mobile learning approach individually.

Owing to the rapid advancement of mobile technologies, the types of mobile devices adopted by researchers and educators have been significantly changed in the past decade. Figure 3 shows the types of mobile devices adopted in the 2008–2012 applications. It is found that smartphones (118 studies, 55%) and Personal Digital Assistants (PDAs) (86 studies, 40%) are the most frequently used mobile learning devices, followed by tablet

PCs (22 studies, 6%). Some of the applications did not mention the types of mobile devices adopted, such as the educational usages of podcasting reported by Harris and Park (2008) and the use of video communications to promote peer interactions reported by Smyth (2011).

Figure 3 Mobile devices adopted in the applications in 2008–2012 (see online version for colours)

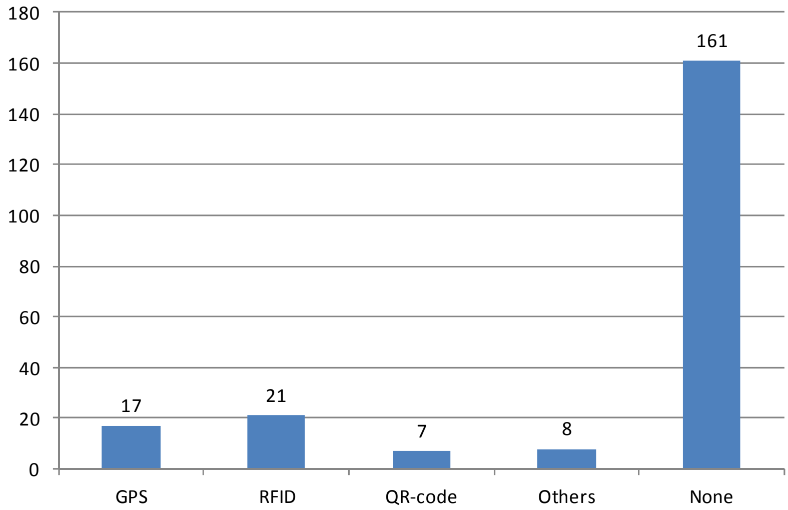


It is found that the number of tablet PC applications increased in 2011 and 2012, although the number was still not large. It should be noted that the applications reported in those journal publications are in fact conducted in an earlier time. That is, the number of publications in 2008 might actually reflect the applications conducted in 2006 or 2007 since it takes time to analyse the data, write and submit the papers, and review and publish the submissions. Therefore, it is predicted that the numbers of smartphone-based mobile learning applications in 2011 and 2012 could be much larger than the numbers revealed in those journal publications. As reported by Renub Research (2011), the worldwide market size of tablet PCs was around US$ 9 billion, and is increasing at a rapid pace. The report has further indicated that tablet PC unit sales will be more than 100 million units by 2015. Therefore, it is reasonable to predict that tablet PCs will gradually become a popular mobile learning device in the coming years.

Similarly, the use of PDAs in educational settings decreased in 2011 and 2012 since they have been replaced by smartphones and tablet PCs. These statistical numbers also imply that the number of PDA applications was decreased in an earlier time.

Another notable trend is the use of sensing technologies in these years, as shown in Figure 4. Most of the studies (161 out of 214) did not report the use of any sensing technology in the mobile learning activities; however, as mentioned above, the statistical data reflect the applications conducted in an early time. It is quite possible that the number of sensing technologies-supported mobile learning applications in 2008–2012 could be much larger than what has been reported in the journals.

Figure 4 Sensing technologies adopted in the applications in 2008–2012 (see online version for colours)



From the statistical results, although Radio Frequency Identification (RFID) seems to be the most frequently used sensing technology (21 out of 214), it mainly works with PDAs, as reported by several studies (Churchill and Churchill, 2008; Chu et al., 2010; Hung et al., 2010). For example, Hwang et al. (2011a) conducted a concept map-based mobile learning activity with PDA and RFID in a butterfly garden. It is inferred that RFID will gradually be replaced by Quick Response Code (QR-code), a low-cost sensing technology that works with smartphones or tablet PCs, since most companies no longer produce PDAs.

A QR-code represents information (i.e. web address or text) as a two-dimensional barcode. It can be scanned and decoded via mobile devices equipped with digital cameras, such as smartphones and tablet PCs. Owing to the popularity of these devices, it can be foreseen that more and more applications will use such low-cost sensing technologies as QR-code for conducting contextual mobile learning activities, in which students are guided and supported to interact with real-world contexts or targets (Liu, 2009; Chen et al., 2011a; Hwang et al., 2011b; Hung et al., 2013). For example, Chen et al. (2011a) employed QR-codes in association with mobile technology to deliver supplementary materials and questions to support students' reading in a paper-based reading activity. Moreover, Hwang et al. (2011b) developed a ubiquitous learning support system with smartphones and QR-codes to assist learners to get help from the right people when encountering problems during their learning activities.

3 Impacts of mobile learning

Figure 5 shows the statistical results of the learning achievements reported by those mobile learning applications. It is found that 131 out of the 214 applications did not measure students' learning achievements. For the 83 applications that reported learning achievements, 69 (around 83%) showed positive results, implying that mobile learning is promising in helping students learn better with proper educational design (Cavus and

Ibrahim, 2009; Gromik, 2012; Uluyol and Agca, 2012; Lin et al., 2012; Ruchter et al., 2010). For example, Cavus and Ibrahim (2009) reported the positive effect of engaging college students in learning new technical English language words using text messaging with mobile phones on their learning achievements. Hwang et al. (2012a) applied an interactive concept map-based mobile learning system to the field trip of an elementary school natural science course and reported the positive effect of the mobile learning approach on the students' learning achievements.

Figure 5 Analysis results of learning achievements reported by the applications in 2008–2012 (see online version for colours)

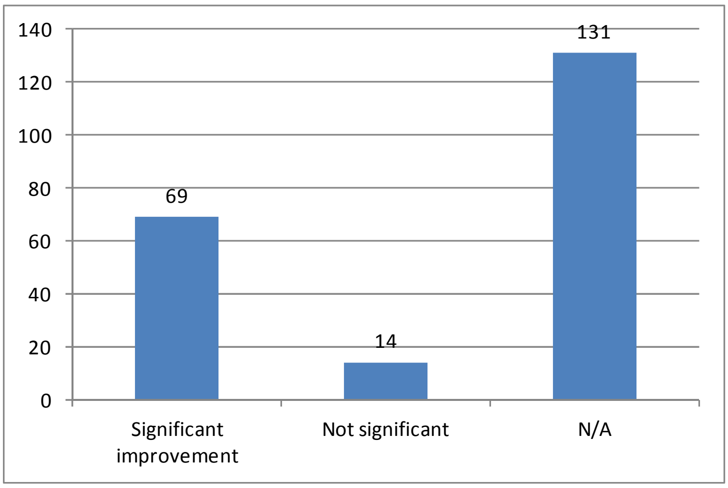


Figure 6 shows the statistical results of the learning motivations reported by those mobile learning applications. In the 31 applications that reported learning motivations, 24 (around 77%) showed positive results, implying that proper use of mobile technologies in educational settings could improve students' learning motivation (Chen et al., 2011b; Huizenga et al., 2009; Ryu and Parsons, 2012). For example, Liu and Chu (2010) reported the positive effect of a mobile game on students' English learning achievement and motivation. Hwang et al. (2012b) conducted an enquiry-based mobile learning activity in a science park and found that the approach could significantly promote the students' learning motivation in comparison with traditional field trips.

Regarding learning interest, among the 44 applications that reported students' learning interest in using mobile devices to learn, 36 (around 82%) showed that the mobile learning approach could significantly improve the students' learning interest in comparison with traditional instruction, as shown in Figure 7. For example, Hoff et al. (2009) reported the positive effect of mobile learning approach on students' learning interest in document annotation activities. Chang et al., (2010) conducted a mobile learning activity for a reading activity in a Chinese language course and found that the use of the mobile technology could promote the students' learning interest and peer interactions. In the same year, Hwang et al. (2010) conducted a mobile learning activity in a butterfly museum and found that the approach had a positive impact on students' learning interest and motivation.

Figure 6 Analysis results of learning motivations reported by the applications in 2008–2012 (see online version for colours)

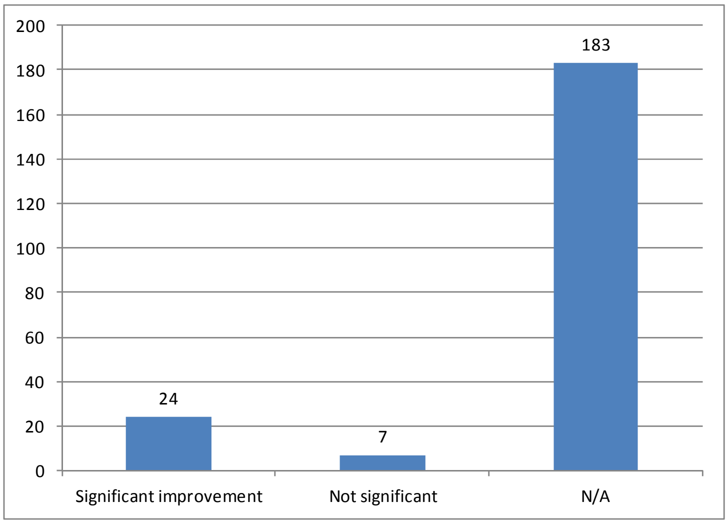
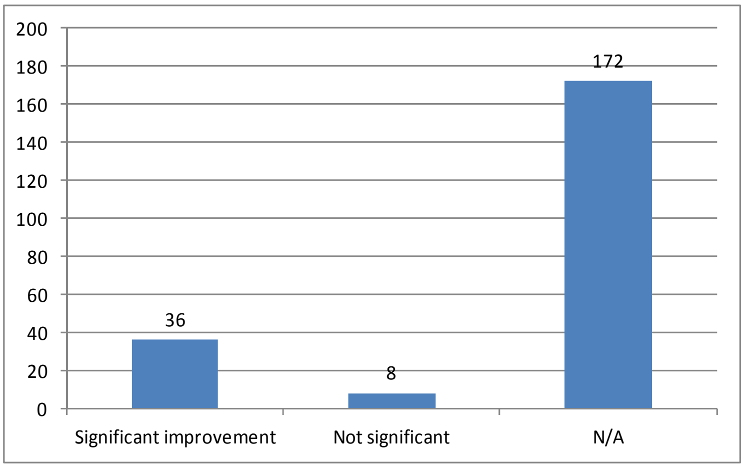


Figure 7 Analysis results of learning interest reported by the applications in 2008–2012 (see online version for colours)



4 Open issues of mobile learning

The review results show that mobile technology is promising in terms of improving students' learning achievements, motivations and interest. However, from the statistical data, it can be seen that mobile technology was seldom applied to several subject domains, such as astronomy, physics, chemistry and arts, implying the need to put more efforts into identifying the potential usage of mobile technologies in these fields.

On the other hand, it is found that most of the studies mainly reported positive effects of the mobile learning approach. Only a few studies have briefly described the difficulties of conducting mobile learning activities, but in a brief and superficial manner, such as the drawbacks of the small screen size, insufficient battery power and unstable network access when using mobile and wireless communication technologies (Chen et al., 2009; Huang et al., 2010; Shih et al., 2011). Recently, some researchers have tried to investigate the split-attention and redundancy effects raised in designing mobile learning content on students' learning achievements and absorption (Liu et al., 2012), which suggest that, to reduce students' cognitive load, it would be better to avoid providing redundant learning content that could be obtained via observing the real-world learning targets. Therefore, it is worth investigating the possible difficulties and negative effects of applying mobile technologies to educational settings, and proposing applicable mobile technology-supported learning models accordingly. The lead-in of Augmented Reality (AR) technologies could be a solution to address this issue (Kamarainen et al., 2013).

Another open issue of mobile learning studies is the analysis of students' learning behaviours and learning patterns, which can be carried out by recording, coding and analysing the interactions between learners, mobile learning systems and the real-world contexts. To achieve this aim, wireless communications and sensing technologies are needed. Along with the analysis of their mobile learning behaviours, students' personal factors, such as knowledge level and learning styles, can also be taken into account.

The advancement of new computer technologies and devices, such as AR and Google glasses could also bring new research issues of mobile and ubiquitous learning. AR technology enables the learning systems to combine digital learning supports (e.g. hints, guidance or supplementary materials) into real-world scenarios at the right place and in the right time via mobile devices, such as mobile phones, tablet computers and Google glasses (Dunleavy et al., 2009). Researchers have indicated three main features of an AR-based system: incorporating real and virtual objects into reality, collaborating between real and virtual objects and real-time interactions between real and virtual objects (Azuma et al., 2001). In comparison with conventional mobile learning that treats digital learning contents and real-world targets as two individual resources, AR-based learning could better comply with the spatial contiguity and temporal contiguity principles proposed by Mayer (2001) and Mayer and Moreno (2003) that integrated presentation of multiple learning resources benefits students more than separate presentation. Therefore, it is worth investigating the effects of using those new technologies on students' mobile learning performance and perspectives.

5 Conclusions

From the review of the 2008–2012 publications as well as earlier surveys reported by several previous studies (Hsu et al., 2012; Hwang and Tsai, 2011; Wu et al., 2012b), it is apparent that mobile technologies have been increasingly applied to formal and informal education (Wong and Looi, 2011). Moreover, from the review of this study, it can be seen that the mobile learning approach has great potential in improving students' learning achievements, motivations and interest if proper learning strategies or supports are provided during the learning process. Several researchers have therefore indicated the importance of developing or applying effective strategies in improving students' mobile learning performance, such as problem-based learning guidance, knowledge construction tools (e.g. concept maps), issue-based discussions, collaborative learning, enquiry-based learning design, project-based learning activities, peer assessment strategy and digital storytelling (Hsu et al., 2013; Hung et al., 2013). This implies that mobile technologies merely provide an opportunity for helping students learn better, not a solution to this objective. That is, the lead-in of proper learning strategies or tools is the key to the success of mobile technology-enhanced learning.

In the meantime, it is also important to investigate the possible negative effects and limitations of using mobile devices in educational settings, e.g. loss of concentration in learning with mobile devices, incensement of cognitive load owing to the rich information from both the real world and the digital world, and the limitations of using touch screen in doing some learning tasks (e.g. developing concept maps and inputting a large amount of texts). It is also important to investigate the factors that might affect students' mobile learning performance, such as the lack of self-regulation in using mobile devices, the attraction of gaming or social network software and improper learning design.

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