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Review of trends from mobile learning studies: A meta-analysis

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ABSTRACT

Two previous literature review-based studies have provided important insights into mobile learning, but the issue still needs to be examined from other directions such as the distribution of research purposes. This study takes a meta-analysis approach to systematically reviewing the literature, thus providing a more comprehensive analysis and synthesis of 164 studies from 2003 to 2010. Major findings include that most studies of mobile learning focus on effectiveness, followed by mobile learning system design, and surveys and experiments were used as the primary research methods. Also, mobile phones and PDAs are currently the most widely used devices for mobile learning but these may be displaced by emerging technologies. In addition, the most highly-cited articles are found to focus on mobile learning system design, followed by system effectiveness. These findings may provide insights for researchers and educators into research trends in mobile learning.

1. Introduction

Recent developments in communications and wireless technologies have resulted in mobile devices (e.g., PDAs, cell phones) becoming widely available, more convenient, and less expensive. More importantly, each successive generation of devices has added new features and applications, such as Wi-Fi, e-mail, productivity software, music player, and audio/video recording. These developments have prompted educators and researchers to take a pedagogical view toward developing educational applications for mobile devices to promote teaching and learning, and research on mobile learning has expanded significantly (Kukulska-Hulme & Traxler, 2007).

This growing body of literature has focused on several broad areas of inquiry such as the effectiveness of mobile learning (e.g., Al-Fahad, 2009; Baya'a & Daher, 2009; Evans, 2008; Lu, 2008; Mcconatha & Praul, 2008; Shen, Wang, & Pan, 2008; Thornton & Houser, 2005) and the development of mobile learning systems to assist student learning (e.g., Chen & Hsu, 2008; Chen, Kao, & Sheu, 2003; Ketamo, 2003; Sung et al., 2005). We believe each study provides valuable insight into issues related to mobile learning, and two reviews have synthesized the results of previous studies to identify broader research trends. Hwang and Tsai (2011) took reviewed six major technology-enhanced learning journals in terms of number of articles published, research sample group selected, major contributing countries, and research learning domains. Hung and Zhang (in press) used text mining techniques to conduct a similar examination (i.e., number of articles published, major contributing countries, etc.).

We believe these two literature reviews provide a valuable synthesis of mobile learning issues, but further examination is warranted based on different research directions. The two literature reviews failed to examine or categorize research trends from the standpoint of research purposes, methodologies, and outcomes. The present study finds these factors represent the overall research trends and patterns in the field. In addition, the two literature reviews failed to examine or analyze the mobile devices from the standpoint of teaching- and learning-assistance, and their critical role in ubiquitous learning. More importantly, the development and usage patterns of technology are

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changing quickly, requiring an up to date analysis of trends in mobile device types and functionality, along with learner types and the use of mobile devices in various disciplines and courses. For example, while Hwang and Tsai (2011) showed the distribution of research sample groups and research learning domains, the present study provides a more comprehensive examination and analysis of mobile devices, learners, disciplines and courses.

In addition, this study attempts to provide an analysis of highly-cited articles by assessing the impact of published articles on practice, with findings that can provide researchers with good examples from high-quality studies in related fields. Based on an analysis process used in the e-learning field by Shih, Feng, and Tsai (2008), this study selected highly-cited articles from each research purpose category for further analysis with the expectation that the results can provide practical insights for a broad range of researchers and educators in the field, and help younger scholars not only to identify contemporary research directions, methods, and trends, but also to understand influential works and individuals in their major subject domains. Understanding trends in recent studies can also help educational policymakers to plan additional inquiries and encourage the consideration of mobile learning as a teaching- and learning-assistance tool both within and beyond the classroom.

In sum, this study systematically reviews and synthesizes the relevant literature through a meta-analysis (Glass, 1976; Hossler & Scalese-Love, 1989; Ke, 2009) to provide a more comprehensive analysis of previous studies. Specifically, the present study poses the four research questions: (1) What are the major research purposes, methodologies, and outcomes addressed in mobile learning studies? (2) What types of mobile devices are mainly used in assisted learning and what are the general types of mobile learners? (3) How are different categories of disciplines and courses represented among mobile learning studies? (4) What are the highly-cited articles in studies of mobile learning?

2. Literature review

2.1. Definition of mobile learning

Mobile learning is one of the key current trends of educational applications for new technologies. O'Malley et al. (2003: p6) have defined mobile learning as taking place when the learner is not at a fixed, predetermined location, or when the learner takes advantage of learning opportunities offered by mobile technologies. Kukulska-Hulme (2005) defined mobile learning as being concerned with learner mobility in the sense that learners should be able to engage in educational activities without being tied to a tightly-delimited physical location. Thus mobile learning features learners engaged in educational activities, using technology as a mediating tool for learning via mobile devices accessing data and communicating with others through wireless technology.

2.2. Categories of research directions regarding mobile learning

Previous studies of mobile learning fall into two broad research directions: evaluating the effectiveness of mobile learning, and designing mobile learning systems. Most research in the former showed positive effectiveness. For example, Evans (2008) used observation to describe a study of the effectiveness of mobile learning in the form of podcasting in a business course for university students, with students finding podcasts to be preferable to their textbook as a learning aid. Al-Fahad (2009) surveyed the attitudes and perceptions of higher education students toward the effectiveness of mobile learning, and found that mobile learning could improve retention among undergraduate and M.D. students. Baya'a and Daher (2009) conducted experiments to explore the effectiveness of mobile learning while using mobile phones in an Arab-language middle school in Israel, and found that students responded positively to the use of mobile phones in learning mathematics.

These positive results are counterbalanced by several neutral or negative findings regarding the effectiveness of mobile learning. Ketamo (2003) developed an adaptive learning environment entitled xTask, with results showing that mobile technologies can generally bring some added value to network-based learning but they cannot replace conventional computers. Doolittle and Mariano (2008) examined the effects of individual differences in working memory capacity (WMC) on learning from an historical inquiry multimedia tutorial in stationary versus mobile learning environments using a portable digital media player, with results showing that students in a stationary instructional environment performed better, while interaction effects indicated that low-WMC students performed most poorly in a mobile instructional environment.

For the second research direction, researchers designed mobile systems to fit their courses. For example, Ullrich, Shen, Tong, and Tan (2010) described the mobile live video learning system (MLVLS) developed at the Shanghai Jiao Tong University for computer sciences courses, and found that mobile devices were significantly more widely used than desktop or laptop computers. de-Marcos et al. (2010) presented an application designed for mobile phones designed to reinforce students' knowledge by means of self-assessment, and found it improved student achievement, especially amongst younger learners, with a relatively low impact on current teaching activities and methodologies. Smørdal and Gregory (2003) reported on a project, KNOWMOBILE, that explored how wireless and mobile technologies (e.g., PDAs) may be useful in medical education and clinical practice, particularly for accessing net-based information, and suggested that PDAs should be regarded as gateways to complicated webs of interdependent technical and social networks.

2.3. Findings and inspiration from previous mobile learning reviews

Two previous literature reviews studied research trends in mobile learning. Hung and Zhang (in press) used text mining techniques to investigate research trends in 119 academic articles on mobile learning from 2003 to 2008 taken from the SCI/SSCI database. In general, they investigated publication date, publication category, taxonomy, article clusters, and country, university and journal of origin. Results showed that articles on mobile learning increased from 8 in 2003 to 36 in 2008; the most popular domains in mobile learning studies are effectiveness, evaluation, and personalized systems and studies on strategies and frameworks are more likely to be published.

Hwang and Tsai (2011) reviewed journals (BJET, C&E, ETS, ETR&D, JCAL and IETI) in the SSCI database from 2001 to 2010, selecting 154 articles on mobile and ubiquitous learning, and noting number of articles published, research sample groups selected, research learning domains, and country of origin. Their findings included the following: the volume of research in mobile and ubiquitous learning greatly

expanded between 2006 and 2010; higher education students were the most frequent research populations, followed by elementary school students and high school students; most studies did not explicitly focus on any particular learning domain but rather investigated the motivation, perceptions and attitudes of students toward mobile and ubiquitous learning, along with course-orientation for engineering (including computers), language and art, and science; and most articles were contributed from US-based authors, followed by authors in the UK and Taiwan.

The above-mentioned studies offer syntheses crucial to understanding issues related to mobile learning, but are incomplete. For example, they fail to account for the distribution of research purposes and methods of among the various articles, along with the type of mobile learning devices used. This study adopts a meta-analysis method in examining these trends in mobile learning studies.

3. Method

A systematic review and analysis was conducted from a data pool consisting of computerized bibliographic databases (e.g., Wiley InterScience, SAGE, SDOL, and ERIC). The procedure was based on the rigorous protocol developed by Glass (1976), Hossler and Scalese-Love (1989) and Ke (2009). The steps for inclusion/exclusion criteria, data sources and search strategies, and data coding and analysis are discussed below.

3.1. Inclusion/exclusion criteria

To be included in this meta-analysis, each study had to meet the criteria indicated in Table 1.

3.2. Data sources and search strategies

The studies included in this meta-analysis were located through a comprehensive search of publicly available literature, mostly through manual electronic searches of the following databases: ERIC, Science Direct Onsite (SDOS), SAGE Journal Online, ProQuest, Wiley InterScience, ACM Digital Library, JSTOR, Elsevier Science (Elsevier)/SDOL, and informaworld. Manual searches were also conducted for *Journal of Computer Assisted Learning*, *Computer in Human Behavior*, *British Journal of Educational Technology*, *Journal of Educational Technology & Society*, and *The International Review of Research in Open and Distance Learning*. Although search strategies varied depending on the tool used, search terms included the keywords "mobile learning" or "M-learning" with "instruct," "teach," "context-aware" "adaptive," "wireless," "situated learning," or "activities".

Our search produced 887 results from previously-used search terms (see Table 2), including 448 duplicates which were deleted. Two researchers then independently confirmed the inclusion/exclusion criteria for each study. The intercoder agreement rate for coding was 94.47%. Disagreements between the two coders were resolved through discussion and further review of the disputed studies. In total, 164 studies met the inclusion criteria and were used in analyses.

3.3. Data coding and analysis

Ten features related to the quality of study research methodology were coded including (a) research purpose, (b) learner demographic (e.g., elementary, secondary, post-secondary, higher education, adult, or disabled), (c) method (e.g., survey, experiment, etc.), (d) use of mobile devices, (e) discipline-orientation (e.g., humanities, social sciences, natural sciences, formal sciences, applied sciences and professional studies), (f) courses, (g) educational contexts (i.e., formal learning, non-formal learning and informal learning), (h) learning outcome (i.e., positive, negative and neutral), and (i) article citation counts. During data analysis, low-quality studies were excluded from the synthesis. In the current analysis, a quantitative study was considered low quality and excluded if it did not depict its methodological design features such as sample size and procedure. Qualitative studies were excluded if they failed to provide a rich description such as mobile learning outcomes, or appeared to rely more on the author's experience rather than field observations.

4. Results

Of the 164 studies published on mobile learning applications in educational contexts from 2003 to 2010, frequency of publication increased from low-to-mid single digits from 2003 to 2006, to low double-digits from 2007 to 2009, and then jumped to 106 in 2010. Below, we detail the results of our meta-analysis based on our three research questions.

Table 1
Inclusion and exclusion criteria.

Inclusion criteria	Exclusion criteria
a. Must involve mobile learning as a primary condition. b. Must include an identifiable learner level. All learner levels are admissible. c. Must include mobile devices while learners are learning. d. Must involve education activities when implementing mobile learning. e. Must be a publicly available or archived periodical article. f. Must be published between January 2000 and December 2010.	a. Mobile learning not used for educational purposes. b. Conference papers or book chapters are excluded.

Table 2
Initial search results for mobile learning.

Database	Frequency	Periodical	Frequency
ACM	7	International Journal of Interactive Mobile Technologies (IMT)	40
informaworld	74	British Journal of Educational Technology (BJET)	34
SAGE	1	Journal of Computer Assisted Learning (JCAL)	83
ERIC	90	Journal of Educational Technology & Society (JETS)	37
SDOS	60		
IEEE	36	Computers in Human Behavior (CHB)	2
ProQuest	16	Computers and Education (C&E)	109
SDOL	163	The International Review of Research in Open and Distance Learning (IRODL)	37
Wiley	98		

4.1. Research question 1: major research purposes, methods, and outcomes

4.1.1. Distribution of research purposes

We classified each article into one of four categories according to its research purpose: (1) evaluating the effects of mobile learning, (2) designing a mobile system for learning, (3) investigating the affective domain during mobile learning, or (4) evaluating the influence of leaner characteristics in the mobile learning process. As seen in Fig. 1, evaluating the effects of mobile learning was the most common research purpose (58%), followed by designing a mobile system for learning (32%), investigating the affective domain during mobile learning (5%) and evaluating the influence of leaner characteristics in the mobile learning process (5%).

4.1.2. Distribution of research methods

We classified the research purposes as one of two types: (1) evaluation-dominant with application-minor or (2) design-dominant with evaluation-minor. The former applies to mobile learning systems and evaluates their effectiveness, while the latter designs mobile systems and evaluates their effectiveness. Purposes 1, 3 and 4 belonged to the former while purpose 2 belonged to the latter.

Fig. 2 indicates that, for purpose 1 (evaluating the effects of mobile learning), researchers primarily relied on surveys (26 studies), followed by experimental research methods (20) and descriptive methods (7). For purpose 2 (evaluating the influence of learner characteristics in the mobile learning process), experimental research methods were used most often (4 studies), followed by surveys (2), descriptive methods (1) and observation (1). For purpose 3 (investigating the affective domain during mobile learning), only two methodologies were used: surveys (6) and interviews (1). Finally, for purpose 4 (designing a mobile system for learning) surveys were the most commonly used methodology (16 studies), followed by experimental research methods (14), descriptive methods (8), case studies (2) and observation (1).

4.1.3. Distribution of research outcomes

Fig. 3 indicates that 86% of studies reported positive research outcomes, while only 4% and 1% respectively reported neutral and negative outcomes.

4.2. Research question 2: types of mobile devices used to assist learners, and types of learners

4.2.1. Distribution of educational contexts by mobile device

Based on research by Merriam, Caffarella, and Baumgartner (2007) and Cedefop (2011), we identified three different categories of educational context: formal education, non-formal education and informal education. As seen in Table 3, in formal education contexts, higher education institutions favored mobile phones (34 studies), followed by PDAs (30) and laptops (7), while PDAs were more commonly used in elementary schools (18 studies). In non-formal education contexts, mobile phones were still predominant (5 studies), but the frequency of use is conspicuously lower than in formal educational use in higher education institutions. Similarly, mobile phones are used in informal education (6 studies). As seen in Table 3, aside from mobile phones and PDAs, other devices and mobile services (e.g., mp3/mp4 players, iPods, cameras, podcasts, GPS devices, and satellite TV), are applied in all three educational contexts but with very low frequencies.

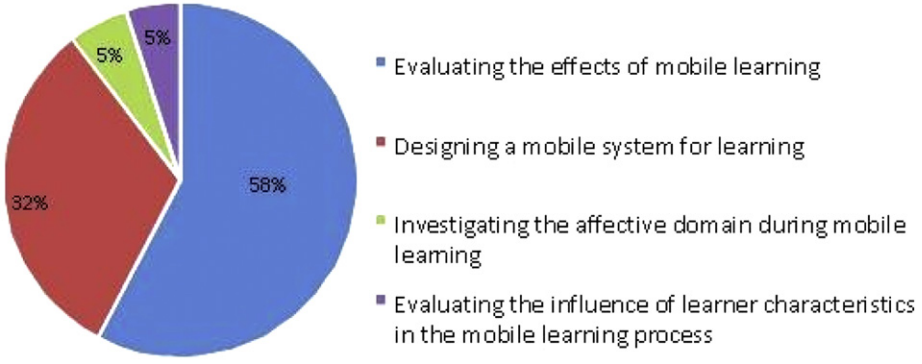

Fig. 1. Distribution of mobile learning studies by research purpose.

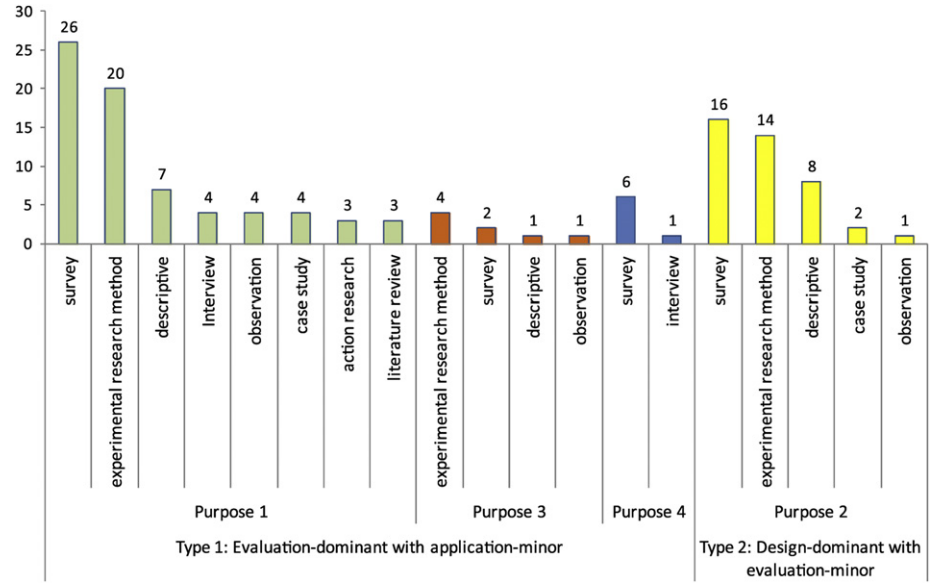

Fig. 2. Classification of mobile learning studies by methodology.

For example, mp3/mp4 players (3 studies) were found in higher education institutions and iPods (1 study) were found being used in non-formal learning.

4.2.2. Distribution of mobile learners by year

Table 4 indicates that mobile learning is most frequently used by higher education students (51.98%), followed by elementary school students (17.51%), adult learners (12.43%), secondary (post-secondary) school students (8.47%) and disabled students (0.56%), and that the number of mobile learners in many contexts increased sharply after 2009.

4.2.3. Distribution of mobile devices by year

Table 5 indicates that, among the 164 studies, mobile phones were most commonly used for mobile learning (36.55%), followed by PDAs (30.96%), laptop computers (9.14%), iPods (4.06%), mp3/mp4 players (2.54%), podcasts (2.03%), and cameras (1.52%). In addition, the choice of device changed over time with the evolution of technology. For example, iPods are first used in mobile learning in 2008, while GPS is not used until 2010, indicating that, with time, studies began to expand their definition of mobile devices used as teaching tools.

4.3. Research question 3: representation of academic disciplines and courses

4.3.1. Distribution of mobile learning by academic disciplines and courses

An academic discipline is a branch of knowledge that is taught and researched at the college or university level. In the early twelfth century, academics in Europe were divided into Theology, Medicine, Law and the Arts (Oleson & Voss, 1979). However, in the early 20th century, new disciplines such as education and psychology were added. This study adopted the taxonomy developed by Becher (1994),

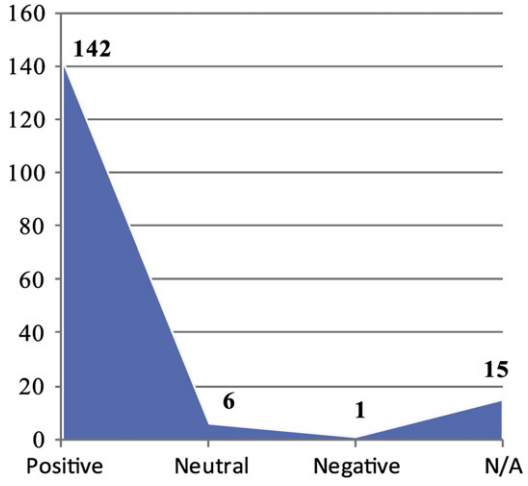

Fig. 3. Distribution of research outcomes.

Table 3
Distribution of educational contexts by mobile device.

Mobile devices	Formal education[a]			Non-formal Education	Informal Education	N/A	Sum
	Elementary schools	Secondary (post-secondary) schools	Higher Education institutions				
Mobile phones	4	3	34	5	6	17	69
PDA	18	1	30	1	4	10	64
Laptops	3	1	7	1	2	5	19
Mp3 player/Mp4 player	0	0	3	1	1	0	5
iPod	0	0	5	1	1	0	7
Camera	1	0	0	1	1	0	3
Podcasts	0	0	3	1	0	0	4
GPS	0	0	0	0	1	0	1
Satellite TV	0	0	0	0	1	0	1
Portable DVD player	0	0	1	0	0	0	1
Electronic dictionaries	0	0	1	0	0	0	1
N/A	2	0	11	2	1	4	20
Sum	28	5	95	13	18	36	195

[a] Formal education is highly institutionalized, bureaucratic, curriculum driven, and formally recognized with grades, diplomas, or certificates, whereas, non-formal education tend to be short-term, voluntary, and have few if any prerequisites; furthermore, informal education is learning that results from daily life activities related to work, family or leisure, it is not structured and typically does not lead to certification.

Franklin (1999), and Wanner, Lewis, and Gregorio (1981) which identifies five major categories of academic discipline: humanities, social sciences, natural sciences, formal sciences, and the professions and applied sciences. Each discipline features different sub-disciplines. The humanities include history, languages and linguistics, literature, performing arts, philosophy, religion and visual arts. The social sciences include anthropology, archeology, area/regional studies, cultural and ethnic studies, economics, gender and sexuality studies, geography, political science, psychology and sociology. The natural sciences include the space sciences, earth sciences, life sciences, chemistry and physics. The formal sciences include computer science, logic, mathematics, statistics and systems science. The professions and applied sciences include agriculture, architecture and design, business, divinity, education, engineering, environmental studies and forestry, family and consumer science, health sciences, human physical performance and recreation, journalism, media studies and communication, law, library and museum studies, military sciences, public administration, social work and transportation.

Based on these classifications, Fig. 4 indicates that studies of mobile learning for educational purposes focused most frequently on applications in the professions and applied sciences (29%), followed by humanities (20%), formal sciences (16%), social sciences (4%) and natural sciences (3%). In terms of sub-disciplines, languages and linguistics courses were the most common focus (17.05%), followed by computer science (13.07%), health sciences (10.23%), environmental studies and forestry (10.23%), physics (2.27%), business (2.27%), and journalism/media studies/communication (2.27%).

4.4. Research question 4: analysis of highly cited articles

4.4.1. Distribution of highly cited articles

To identify highly-cited articles, citation counts of the 164 studies were analyzed in the SSCI (as on February 3, 2012). Shih et al. (2008) stressed that more frequently-cited articles are usually those that receive greater recognition by others in related fields. These highly-cited articles could raise fundamental issues for future research. The fifteen articles with the highest citation counts in different research purpose categories were selected for analysis. Five articles were categorized as “Evaluating the effects of mobile learning”; eight were categorized as “Designing a mobile system for learning purposes”; and one article each was categorized as “Investigating the affective domain during mobile learning” and “Evaluating the influence of learner characteristics on the mobile learning process”. Table 6 presents the research purposes, participants, methods, mobile device types, disciplines/courses and SSCI citation counts of these 15 studies.

The citation counts for these fifteen articles ranged from 13 to 78, with the most highly cited study (78 citations) falling in the category of “Designing a mobile system for learning purposes” (Chen et al., 2003), and focused on developing a mobile learning system to provide scaffolding for students learning about bird-watching. The second-most highly cited study (47 citations) was categorized as “Evaluating the effects of mobile learning” (Evans, 2008), and investigated the effectiveness of podcasts for teaching undergraduate students. The third and the fourth most highly cited studies (43 and 41 citations, respectively) were both categorized as “Designing a mobile system for learning

Table 4
Distribution of mobile learners.

Year	Higher education institution students	Elementary school students	Secondary (post-secondary) school students	Adult learners[a]	Disabled students	N/A
2003	1	1	0	1	1	0
2004	0	1	0	0	0	0
2005	5	1	1	0	0	0
2006	1	0	0	0	0	0
2007	9	0	0	2	0	0
2008	10	0	1	1	0	1
2009	16	2	2	4	0	1
2010	50	26	11	14	0	14
Sum	92	31	15	22	1	16

[a] Adult learners work full-time or want to learn via mobile devices.

Table 5
Distribution of mobile devices by year.

Mobile devices	2003	2004	2005	2006	2007	2008	2009	2010	Sum
Mobile phones	2	0	2	0	6	6	10	46	72
PDA	2	1	5	1	2	6	9	35	61
Laptops	0	0	2	0	1	0	1	14	18
iPod	0	0	0	0	0	2	3	3	8
Mp3 player/Mp4 player	0	0	0	0	0	0	1	4	5
Podcasts	0	0	1	0	3	0	0	0	4
Camera	0	0	0	0	0	0	0	3	3
GPS	0	0	0	0	0	0	0	1	1
Satellite TV	0	0	0	0	0	0	0	1	1
Portable DVD player	0	0	0	0	0	0	1	0	1
Electronic dictionaries	0	0	0	0	0	0	1	0	1

purposes" (Thornton & Houser, 2005 and Zurita & Nussbaumw, 2004). The former study created a Vidioms system using mobile phones and PDAs to assist English idiom learning, while the latter study developed a constructivist learning environment supported by handheld devices for the teaching of reading in elementary schools. Moreover, we found one study with 19 citations (Chu, Hwang, & Tsai, 2010) that, given its recent publication, could be expected to have potential for a high citation count in the future.

This subsection examines the highly cited articles. For other results, such as research purposes, methods, outcomes, mobile devices and disciplines/courses, readers can refer to the descriptions of the previous subsections.

5. Discussion

Both Hwang and Tsai (2011) and Hung and Zhang (in press) provide valuable syntheses for studies in mobile learning. For example, the two studies showed the increasing trend and broadening distribution of countries contributing to studies in mobile learning. However, their approach is still incomplete and the topic needs to be further explored from different directions. This study provides important results and new findings. For example, the research purposes of most mobile learning studies center on effectiveness, followed by mobile learning system design. Moreover, mobile phones and PDAs may be the two devices most commonly used for mobile learning, but new devices may emerge as technology advances. Findings are further described below.

5.1. Most studies of mobile learning focus on effectiveness, followed by mobile learning system design

As seen in Fig. 1, of the 164 studies, 58% took evaluating the effectiveness of mobile learning as the primary research purpose. This focus on evaluation is a new finding not raised in previous literature surveys. More importantly, this result corresponds with surveys of other technology-assisted learning contexts. For example, Vogel et al. (2006) indicated that most studies on game-based learning focus on effectiveness. The second-most frequently-cited research purpose was mobile learning system design (32%), which is also a new finding. More importantly, we found that the number of studies devoted to mobile learning system design increased over time, which may be due to rapid technology development (e.g., new smart phones and wireless data networks) combined with the willingness of researchers to trial new technologies in developing mobile learning systems.

5.2. Most mobile learning studies adopted surveys and experiments as the primary research methods

Fig. 2 shows that, among the 164 studies, surveys were the primary research method (50 studies), followed by experimental research methods (38) and, regardless of research purpose (i.e., evaluation-dominant with application-minor or design-dominant with evaluation-minor), quantitative approaches were favored over qualitative approaches. This is a new finding which corresponds with findings in other technology-assisted learning contexts. For example, Zawacki-Richter, Bäcker, and Vogt (2009) found that quantitative methods dominated distance education studies from 2000 to 2008, followed by qualitative methods or triangulation methods.

5.3. Most mobile learning studies feature positive outcomes

Fig. 3 shows that 86% of the 164 mobile learning studies present positive outcomes. This is a new finding which corresponds to findings in other technology-assisted learning contexts. For example, Ke (2009) applied a meta-analysis approach to find that studies of game-based learning generally have positive outcomes.

5.4. Mobile phones and PDAs currently are the most widely used devices for mobile learning, but may be displaced by emerging technologies

In the context of mobile learning, device type has a critical impact on teaching and learning. Table 3 shows that mobile phones and PDAs together account for over 75% (69/195 + 64/195) of all mobile devices used in educational contexts.

More importantly, technology advances quickly and new types of mobile devices are emerging that can be applied to education. For example, Martin et al. (2011) used the predictions from Horizon reports from 2004 to 2010 (covering 2004–2014), to analyze technologies that have impacted education in the past or are likely to have an impact in the future. Horizon report 2007 suggested that the use of mobile phones in mobile learning, particularly in higher education, would expand dramatically after 2009, which corresponds with our findings. In addition, Horizon report 2010 predicted that future mobile devices would add functions such as mobile computing, open content, e-books, gesture-based computing, and visual data analysis.

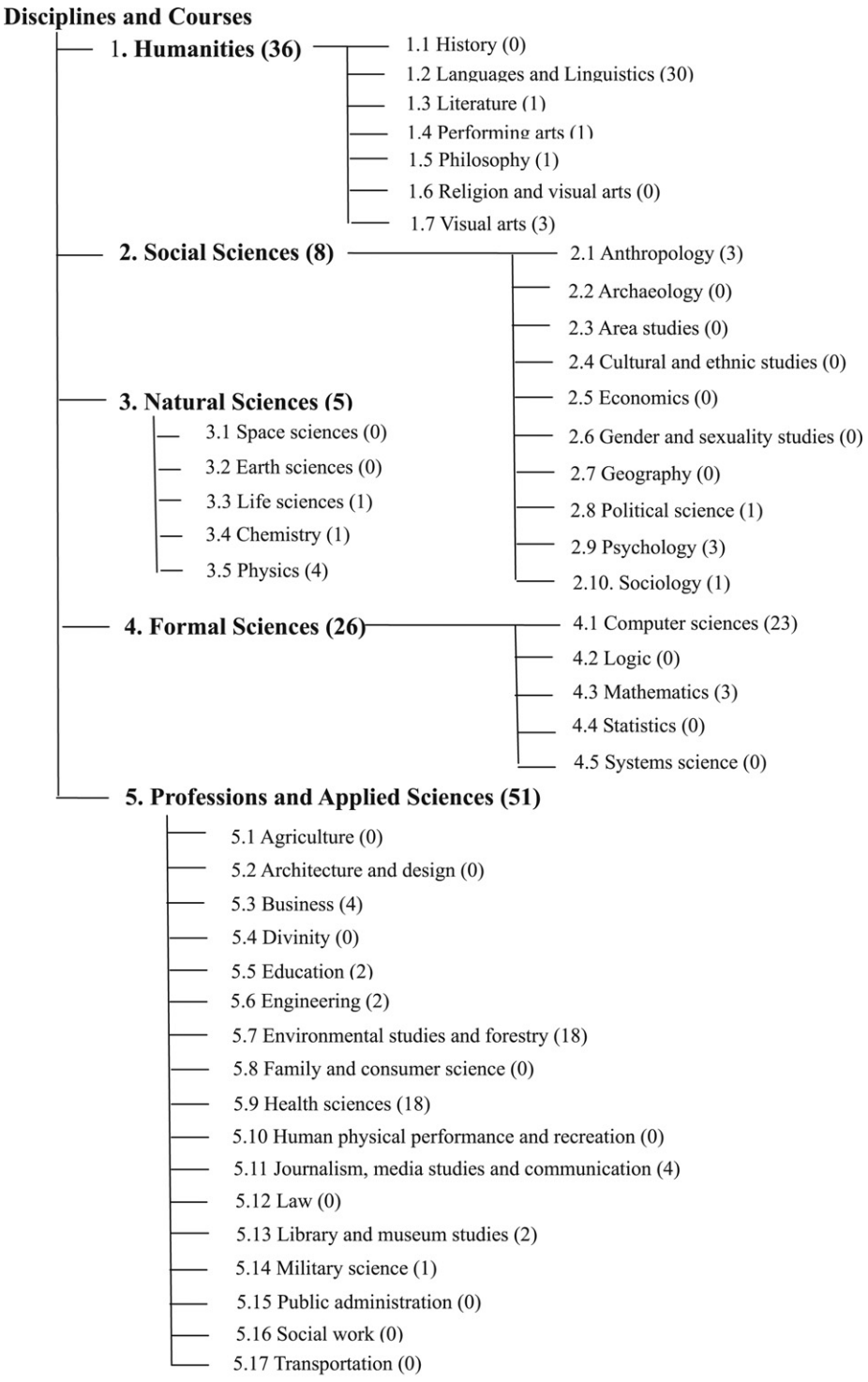

Fig. 4. Distribution of disciplines and courses.

5.5. Use of mobile devices for learning is most common in higher education followed by elementary schools

Table 4 shows that mobile learning is most frequently used in teaching and learning contexts for higher education students (51.98%), followed by elementary school students (17.51%), which corresponds with findings from Hwang and Tsai (2011). More importantly, the present study further indicates a significant jump in mobile learning activity in higher education institutions in 2006, with studies based in higher education institutions (1 in 2006, to 50 in 2010) and in elementary schools, (2 in 2009, to 26 in 2010).

Table 6
Analysis of high-citation studies regarding mobile learning.

Research purposes	Study	Participants	Methods	Mobile devices	Disciplines/Courses	SSCI citation[a]
Evaluating the effects of mobile learning	Evans, (2008)	University students	Observation	iPod	Professions and applied sciences/Business	47
Evaluating the effects of mobile learning	Copley, (2007)	Undergraduate students	Survey	Audio podcasts and video podcasts	Professions and applied sciences/Military sciences	31
Evaluating the effects of mobile learning	Chen, Chang, & Wang, (2008)	University students	Survey and interview	cell phone and PDA	Formal sciences/Computer sciences	21
Evaluating the effects of mobile learning	Corlett, Sharples, Bull, & Chan, (2005)	University students	Survey and focus group	Compaq iPAQ 3760 handheld computer	N/A	18
Evaluating the effects of mobile learning	Garrett, & Jackson, (2006)	Medical school students	Interpretive phenomenology and survey	PDA	Professions and applied sciences/Health sciences	15
Evaluating the influence of learner characteristics on the mobile learning process	Wang, Wu, & Wang, (2009)	M-learning users	Survey	PDA	N/A	15
Investigating the affective domain during mobile learning	Walton, Childst, & Blenkinsopp, (2005)	Community health students at University	Literature review and survey	PDAs, laptops and WAP phones	Professions and applied sciences/Health sciences	17
Designing a mobile system for learning purposes	Chen et al., (2003)	Elementary school students	Descriptive	PDA	Professions and applied sciences/Environmental studies and Forestry	78
Designing a mobile system for learning purposes	Thornton, & Houser, (2005)	Japanese university students	Survey	mobile phones and PDA	N/A	43
Designing a mobile system for learning purposes	Zurita, & Nussbaumw, (2004)	Low-income public school students	Experiment and interview	Handheld devices	N/A	41
Designing a mobile system for learning purposes	Schwabe, & Göth, (2005)	University students	Survey	PDA	N/A	29
Designing a mobile system for learning purposes	Hwang, Yang, Tsai, & Yang, (2009)	University experienced and inexperienced researchers	Experiment and interview	PDA	Natural sciences/Chemistry	22
Designing a mobile system for learning purposes	Chen, & Chung, (2008)	University students	Descriptive and survey	mobile phone and PDA	Humanities/Languages and linguistics	20
Designing a mobile system for learning purposes	Chu et al., (2010)	fifth-grade students	Experiment and interview	PDA	Natural sciences	19
Designing a mobile system for learning purposes	Chen, & Hsu, (2008)	University students	Survey	PDA	Humanities/Languages and linguistics	13

[a] As the record of February 3, 2012.

5.6. Mobile learning most frequently supports learning in the professions and applied sciences, the humanities, and formal sciences

Fig. 4 shows that studies on mobile learning in educational contexts most frequently focus on use in supporting professional subjects and applied sciences (29%), followed by the humanities (20%), and formal sciences (16%). In terms of mobile learning activity in various sub-disciplines, our findings partially support those of Hwang and Tsai (2011). For example, both studies showed mobile learning was often used in computer and language courses. More importantly, the present study found that mobile learning is also widely used in courses related to environmental studies, forestry and health sciences, but considerably less so in other courses such as statistics or law. However, we suggest that mobile learning can be applied to any course or subject matter, and researchers from different disciplines can collaborate to develop suitable applications for under-represented courses.

5.7. Most highly cited articles fall into the categories of mobile learning system design and followed by effectiveness

Table 6 shows that, based on the criterion count being equal to or greater than 40, three highly cited articles fall into the category of "Designing a mobile system for learning purposes" and one article is categorized as "Evaluating the effects of mobile leaning". This focus on highly cited articles is a new finding not addressed in previous literature surveys. More importantly, compared with the results in Fig. 1, this finding reverses the order of the first and the second categories while the order of the third and the fourth categories remains unchanged.

For mobile-based technological development, we found that articles belonging to the category "Designing a mobile system for learning purposes" describe mobile systems developed by researchers and educators prior to any effectiveness evaluation. These systems can present important applications in various disciplines such as bird-watching, learning of professions, applied science/environmental studies and forestry for elementary school students (Chen et al., 2003). These applications are more likely to be cited by other related studies. Also, most of the highly cited articles were published from 2003 to 2005, aside from one article published in 2008. This is probably because, similar to other technology-assisted learning contexts such as the literature surveys of e-learning by Shih et al. (2008), earlier articles have a longer time to be disseminated and cited in other related studies.

6. Conclusions

Two previous literature review-based studies on the use of mobile learning in academic contexts provided valuable insights, but failed to examine the issue from directions such as the distribution of research purposes. This study conducted a systematic meta-analysis to provide more comprehensive analysis of past studies, and discusses the implications of new findings.

The current study presents seven new findings: (1) The research purpose of most mobile learning studies focuses on effectiveness, followed by mobile learning system design. (2) Surveys and experimental methods were the preferred research methods, regardless of whether the research purpose focused on evaluation or design. (3) Research outcomes in mobile learning studies are significantly positive. (4) Mobile phones and PDAs are the most commonly used devices for mobile learning, but these may be replaced in the future by new emerging technologies. (5) Mobile learning is most prevalent at higher education institutions, followed by elementary schools. (6) Mobile learning most frequently supports students in the professions and applied sciences, followed by the humanities and formal sciences. (7) The most highly cited articles fall into the categories of mobile learning system design and followed by effectiveness. In sum, this study of issues in mobile learning presents findings which can help supplement linkages with previous studies and forms an important reference base for the future research in mobile learning.

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