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Research priorities in mobile learning: An international Delphi study

Les priorités de recherche en matière d'apprentissage mobile: Une étude de Delphes internationale

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Abstract

Along with advancing mobile technologies and proliferating mobile devices and applications, mobile learning research has gained great momentum in recent years. While there have been review articles summarizing past research, studies identifying mobile learning research priorities based on experts' latest insights have been lacking. This study employed the Delphi method to obtain a consensus from experts about areas that are most in need of research in mobile learning. An international expert panel participated in a three-round Delphi process involving two cycles of online questionnaires and feedback reports. Participants responded to the question, "What should be the research priorities for the field of mobile learning over the next 5 years?" Ten research categories were identified and ranked in order of priority: 1) teaching and learning strategies; 2) affordances; 3) theory; 4) settings of learning; 5) evaluation/assessment; 6) learners; 7) mobile technologies and interface design; 8) context awareness and augmented reality; 9) infrastructure and management; and 10) country and digital divide. This study also reported expert-generated research statements for each research category and the importance of these research statements rated by the experts themselves. Selected research papers were summarized to help contextualize the discussions of research categories and statements.

Résumé

Avec l'avancement des technologies mobiles et la prolifération des appareils mobiles et des applications, la recherche consacrée à l'apprentissage mobile a récemment pris de l'ampleur. Si des articles ont résumé les recherches antérieures, les études s'appuyant sur les dernières connaissances d'experts pour identifier les priorités de recherche sur l'apprentissage mobile font défaut. La présente étude a utilisé la méthode de Delphes pour obtenir un consensus des experts sur les domaines nécessitant le plus des recherches sur l'apprentissage mobile. Un groupe international d'experts a participé à un processus de Delphes structuré en trois rondes impliquant deux séries de questionnaires en ligne et des rapports de rétroaction. Les participants ont répondu à la question : "Quelles devraient être les priorités de recherche dans le domaine de l'apprentissage mobile pour les cinq prochaines années ?" Dix catégories de recherche ont été identifiées et classées par ordre de priorité : 1) stratégies d'enseignement et d'apprentissage ; 2) affordances ; 3) théorie ; 4) paramètres d'apprentissage ; 5) évaluation ; 6) apprenants ; 7) technologies mobiles et conception de l'interface ; 8) perception du contexte et réalité augmentée ; 9) infrastructure et gestion ; et 10) pays et fossé numérique. Cette étude a également repris les déclarations de recherche énoncées pour chaque catégorie par les experts ainsi que le classement par ordre d'importance des déclarations de recherche selon l'avis de ces experts. Quelques articles choisis ont été résumés pour faciliter la contextualisation des discussions portant sur les catégories de recherche et sur les déclarations.

Introduction

The rapid advancement in mobile technologies in recent years has made innovation in mobile learning possible due to varied affordances. O'Malley et al. (2005) defined mobile learning as "any sort of learning that happens when the learner is not at a fixed, predetermined location, or learning that happens when the learner takes advantage of the learning opportunities offered by mobile technologies." Both are learner-centric, but the first half of the definition points out the mobility and ubiquity aspects of mobile learning, while the second half relates to the concept of affordances. Affordances refer to the tasks or activities made possible by the features or functions of technologies (Hsu, Ching, & Grabowski, 2014). The major affordances of mobile technologies for learning include the following aspects: 1) high device-portability that enables easy access to mobile devices and user mobility (Brown, 2009); 2) relatively strong computing power that gives learners the ability to achieve and complete tasks on small devices with a capability equivalent to larger and less portable devices (Lai & Wu, 2006); 3) always-on and stable Internet connectivity with high bandwidth which allows for instant access to large amounts of information and real-time communication regardless of location (Johnson, Smith, Willis, Levine, & Haywood, 2011). These affordances of mobile technologies make it possible for learning to occur in the real-world contexts relevant to learners. Learners can take the mobile devices anywhere they want to execute tasks or continue their learning processes beyond classrooms. Learning can be ubiquitous and seamless because of the portability and strong computing power of mobile technologies, (Liu, Tan, & Chu, 2009). In addition, the constant Internet connectivity of mobile devices can help promote social learning through communication and collaboration among learners (Zurita & Nussbaum, 2004a). Through sharing knowledge and experiences, learners can develop expertise related to their field or their interest (Lave & Wenger, 1991). Mobile devices afford rich and varied communication and collaboration possibilities (Motiwalla, 2007) that are critical to collaborative knowledge construction.

Parallel to the year-to-year increasing sales number of mobile devices (Gartner, 2011), advancement in mobile technologies and features (Wu, Wu, Cheng, Kao, Lin, & Huang, 2012), and availability of various mobile applications (Hsu, Rice, & Dawley, 2012), there has been growing interest in the educational use of mobile devices/technologies (Rushby, 2012). However, implementing mobile learning, especially regarding the evaluation portion of it, can have challenges due to the ubiquitous nature of mobile learning. Vavoula and Sharples (2009) suggested six challenges in evaluating mobile learning, including capturing and analyzing learning in context and across contexts, measuring mobile learning processes and outcomes, respecting learner/participant privacy, assessing mobile technology utility and usability, considering the wider organizational and socio-cultural context of learning, and assessing in/formality. Kukulska-Hume (2013) also pointed out issues such as privacy, security and trust, and interdependencies with the commercial world, which related to mobile apps sending user information back to app developers and advertisement/analytics companies. Other issues and challenges include classroom management (Kukulska-Hume, 2013), which is complicated by the portability of mobile devices, and further complicated by social media (e.g., YouTube) and social networking applications (e.g., Facebook) available on mobile devices that could distract students during their learning. Also, with the combination of mobile devices and social media applications, there are ethical issues where users/learners can distribute recorded image, audio, and video to social networking sites more easily than ever. These challenges and issues all need to be addressed with appropriate corresponding learning design and pedagogy.

The productivity in mobile learning research (Kukulska-Hulme & Traxler, 2007) that examines learning potential and related critical issues leads to an emerging body of literature. This body of research has started to identify trends of mobile learning research using methods such as content analysis through categorization and classification (e.g., Hwang & Tsai, 2011; Wu et al., 2012) and text mining (e.g., Hung & Zhang, 2012). Those literature reviews examined published articles in journals and proceedings to identify research themes and increasing/decreasing trends. Hwang and Tsai (2011) reviewed 154 articles published between 2001 and 2010 from 6 journals included in the Social Science Citation Index (SSCI). They found that most studies focused on motivation, perceptions and attitudes of students toward mobile and ubiquitous learning. They also found that mobile learning research conducted between 2006 and 2010 has increased significantly in numbers of publications across learning domains such as engineering (including computers), arts and language, science, and social sciences, compared with research conducted between 2001 and 2005. Hung and Zhang (2012) examined 119 refereed journal articles and proceedings (published between 2003 and 2008) retrieved from Science Citation Index (SCI) and SSCI databases, and found that research during that period focused on examining effectiveness of mobile learning, adaptive or intelligent tutoring systems, and personalized mobile learning systems. Wu et al. (2012) analyzed 164 articles published between 2003 and 2010, retrieved from multiple databases and refereed journals. Similar to the findings of Hung and Zhang, Wu et al. found that most mobile learning research focused on effectiveness of mobile learning, followed by mobile learning system design. Wu et al. found that surveys and experiments were the primary research methods during that period. Also, their analysis showed that mobile learning in the context of higher education is most frequently researched (51.98%), followed by elementary school (17.51%), adult learning (12.43%), secondary/post-secondary education (8.47%), and disabled students' learning (0.56%). With a more specific focus on mobile learning pedagogies, Hsu and Ching (2013) reported their review of nine quasi-experimental or experimental studies published between 2004 and 2011 on mobile computer-supported collaborative learning (mCSCL). They analyzed the studies regarding the following aspects related to mCSCL: student (education) level, content domain, group size, mobile software/applications that support collaborative learning, and mobile operating systems. They also reported the types of mCSCL interventions as well as their impact on students' learning performance, engagement, participation, and interaction.

Although the aforementioned review articles can provide valuable input regarding what has been done, they might not be able to capture the latest and upcoming research agendas based on the consensus of the leading mobile learning researchers. The purpose of this paper is to research the collective insight from mobile learning research experts. This paper can help pave the way for meaningful and critical research in mobile learning. It also in part echoes the discussions regarding an agenda for mobile learning in a recent editorial by Rushby (2012). The authors aim to provide instances and directions that can help reveal the various facets and enrich the definitions of mobile learning.

Method

In order to inform the community of the latest research priorities in mobile learning, the Delphi method was selected as an appropriate method for systematically studying priorities in mobile learning research. The Delphi method is a consensus technique (Anderson & Kanuka, 2003) that was developed in the 1950s by the RAND (Research and Development) Corporation to forecast the impact of technology on warfare. Information on the RAND website defines the essential characteristics and goals of the Delphi method in the following statement:

> The method entails a group of experts who anonymously reply to questionnaires and subsequently receive feedback in the form of a statistical representation of the "group response," after which the process repeats itself. The goal is to reduce the range of responses and arrive at something closer to expert consensus (RAND, n.d., para. 1).

This method has been used previously to address various research questions, such as identifying research priorities in educational technology (Pollard & Pollard, 2004), K-12 online education (Rice, 2009), and video-sharing (YouTube) research (Snelson, Rice, & Wyzard, 2012).

The current study invited experts in the field of mobile learning to identify priorities in mobile learning research. The expert panel participated in a three-round Delphi process involving two cycles of online questionnaires and feedback reports. Procedural steps for the three rounds of the Delphi study were as follows:

Round 1

Participants responded to the question, "What should be the research priorities for the field of mobile learning over the next 5 years?" The three authors of this paper reviewed the expert statements submitted in response to this question. Of these three, one is an expert in mobile learning technologies, another is experienced with the Delphi method, and the other has expertise in a variety of learning technologies and research methodologies. Each author reviewed and categorized the statements independently.

Next, all three authors met to discuss the initial categories until consensus was achieved in both (1) identification and naming of each category and (2) placement of statements within each category. This process is consistent with the approach used in previous Delphi studies (e.g., Pollard & Pollard, 2004; Rice, 2009; Snelson et al., 2012). In all, the group of 14 experts generated 70 statements. These responses were consolidated into 40 statements and organized into 10 research priority categories. The statements and categories were used to develop the Round 2 survey.

Round 2

Participants were asked to rate the consolidated statements on a Likert-type scale as to the degree of importance (1 = No Importance, 5 = High Importance). Additionally, experts were asked to prioritize the ten research categories (1 = Highest Priority, 10 = Lowest Priority). Once returned, descriptive statistics for the group ratings and rankings were calculated.

Round 3

Descriptive statistical information about how the group responded, as a whole, was provided to the participating experts. They were asked to review each statement and category, consider the group response and then re-rate the statements and re-rank the categories after taking the information into account. The three-round Delphi process enabled the participants to generate their own opinions about necessary research areas, to prioritize research focus categories, and then to finalize their views based upon consideration from the entire group's opinions. This process, engendering the dynamics of effective group interactions, enabled researchers to gain a consensus from a panel of expert participants in diverse geographical locations about mobile learning research priorities for the next 5 years.

Delphi Panel Experts

The recommended number of Delphi participants to include on an expert panel has varied, such as 10 to 30 (Anderson & Kanuka, 2003) and from 10 to 15 (Delbecq, Van de Ven, & Gustafson, 1975). For the current study, we identified and invited 59 experts to participate, and 14 of them completed all three rounds of survey. The initial process of identifying experts was conducted through a comprehensive review of the literature similar to what was done in a previous Delphi study (i.e., Snelson et al., 2012). The process of identifying experts began with a keyword search in the titles of refereed journal articles through WorldCat, the World's largest online catalog built and maintained by 72000 participating libraries in 170 countries and territories (Wikipedia, 2013). The keywords included ti:handheld or ti:mobile learning or ti:mlearning or ti:m-learning. The authors of mobile learning research were then categorized by the total number of articles they published and served as single/first author. Each author's work was then further examined to make sure the invitation was sent to the authors with research relevant to mobile learning. For example, authors of research focusing on algorithm, mobile network establishment, mobile robots, or specific hardware on mobile devices (e.g., sensors) were excluded. After this process, a total of 41 experts who are first authors of mobile learning refereed articles were identified. Furthermore, four other sources were used to locate and identify 18 additional experts to participate in this study. These included guest editors on mobile learning special issues in important journals in educational technology, editors of notable books on mobile learning (i.e., cited more than 10 times according to Google Scholar), and experts who were identified from the review of references of mobile learning refereed articles. In addition, one of the invited experts who could not participate recommended a list of mobile learning experts from Australia and New Zealand. An invitation was sent to 59 experts in mobile learning to participate in this Delphi study. Fourteen experts, all with doctoral degrees, completed three rounds of survey. Table 1 presents the demographic characteristics of the 14 Delphi panel experts.

Table 1:
Mobile Learning Scholars Demographic Overview (Round 3 Participants, n = 14)

Demographic Item	*n*	%
Gender		
Male	9	64
Female	5	36
Highest Degree		
Doctorate	14	100
Current Position Held		
University Professor	12	86
University Researcher	2	14
Discipline Area		
Archaeology	1	7
Education	8	57
Science & Engineering	1	7
Information Systems/Technology	2	14
Information Management	1	7
Nursing	1	7
Geographical Location		
(based on institution)		
Australia	1	7
Canada	1	7
Finland	1	7
New Zealand	1	7
Taiwan	4	29
UK	2	14
USA	4	29

Note: Percentages are rounded and may not total 100% for some groups of demographic items.

Findings

In this section, we reported and discussed each of the 10 research categories and the 40 research statements generated by the panel of experts to help inform the directions for future research in mobile learning. Among the 10 research categories, the need for research on learning and teaching strategies was identified as the top research priority category by this group of experts (median of 2.0). Following in priority is the need for research on affordances (of mobile technology) (median of 3.0). The complete frequency and percentages of expert rankings are shown in Table 2 with research priority categories arranged in order of median value. In addition, for each research category, we reviewed, selected, and summarized conceptual papers or empirical studies that are representative of the category. In doing so, we hope to provide examples of mobile learning research under each category identified by our panel experts. The inclusion of these studies does not indicate the categories have been saturated with mobile learning research. Instead, it shows what has been done, and how future research can build on the previous work in the areas considered important in the next five years by the panel experts.

Table 2:
Research Priorities Ranked by Experts: Round 3

Category	Number of statements	*Priority ranking, frequency* 1	2	3	4	5	6	7	8	9	10	*Mdn (IQR)*
1. Learning and Teaching Strategies	6	6	3	2	2	0	1	0	0	0	0	2.0 (2.0)
2. Affordances	3	5	1	2	0	2	1	0	1	1	1	3.0 (4.8)
3. Theory	4	0	0	2	6	1	2	2	0	1	0	4.0 (2.0)
4. Settings of Learning	6	0	1	4	2	1	1	3	2	0	0	4.5 (4.0)
5. Evaluation/Assessment	2	1	3	1	1	3	1	1	2	1	0	5.0 (4.5)
6. Learners	4	1	1	0	2	4	2	2	1	1	0	5.0 (2.5)
7. Mobile Technologies and Interface Design	4	0	0	2	0	4	4	1	2	1	0	6.0 (1.8)
8. Context Awareness and Augmented Reality	6	0	3	0	1	0	1	2	3	2	2	7.5 (4.3)
9. Infrastructure and Management	2	1	1	0	0	0	1	2	1	6	2	9.0 (2.0)
10. Country and Digital Divide	3	0	1	1	0	0	0	1	1	1	9	10.0 (1.8)

Note: A ranking of 1 equals 'Highest Priority' and 10 equals 'Lowest Priority'. Mdn, medium value; IQR, interquartile range.

Research Priority Category 1: Learning And Teaching Strategies (6 Statements)

The Delphi experts indicated the highest priority category is to examine strategies for applying mobile technologies to support learning and teaching. Delphi experts recommended six major strategies, including collaborative learning, game-based learning, inquiry-based learning, simulation, information-rich content delivery, and tutoring for context-aware ubiquitous learning. An example of research in this category, more specifically related to collaborative learning, is Boticki, Looi, and Wong (2011). In their study, Boticki et al. applied an experimental research design to study the use of mobile devices to facilitate communication and interaction among primary school students (aged 8 to 9) through a scaffold flexible grouping approach (first in pairs, then groups of 3 and 4). In their intervention, students could use their mobile devices to send invitations to peers who they identified as qualified group members. These members would have the necessary information to help complete the students' task of finding complementary fractions to get the sum of 1. Table 3 lists the six research statements and descriptive statistics for the category of the highest research priority: learning and teaching strategies. In addition to facilitating communication and interaction, other types of intervention of using mobile technologies to support collaborative learning include presenting the individual portions of an assigned learning task and serving as the focal point of interaction (e.g., Roschelle et al., 2009), providing feedback for group learning and instructor teaching (e.g., Zurita and Nussbaum, 2004b), and managing and regulating interaction process (e.g., Chen et al., 2008).

Table 3:
Learning and Teaching Strategies

Expert-generated statements	*Ratings of importance, frequency*					
Research in:	1	2	3	4	5	*Mdn (IQR)*
Collaborative learning and cooperative learning	0	0	4	5	5	4.0 (1.8)
Game-based learning	0	0	2	8	4	4.0 (0.8)
Inquiry-based learning	0	0	1	6	7	4.5 (1.0)
Simulation teaching and learning strategies	0	0	1	10	3	4.0 (0.0)
How to develop information-rich content for delivery on mobile technology	0	0	2	11	1	4.0 (0.0)
Tutoring strategies for context-aware ubiquitous learning	0	1	5	5	3	4.0 (1.0)

Note: A rating of 1 equals 'No Importance' and 5 equals 'Very High Importance'.
IQR, interquartile range.

Research Priority Category 2: Affordances (3 Statements)

The next highest priority category for research in mobile learning involved investigating the affordances of mobile technologies to support teaching and learning. In the context of this paper, affordances refer to the learning or teaching tasks/activities made possible by the features or functions of mobile technologies (Hsu et al., 2014). The tasks and activities need to be guided by the strategies identified in Category 1: Learning and Teaching Strategies. The three research statements listed in Table 4 include the affordances of mobile technology to support: 1) problem representation and problem solving; 2) knowledge construction and collaborative learning; 3) contextualized learning. It is worth noting that collaborative learning appeared in both Category 1 and Category 2, which shows that the experts value the importance and potential of mobile technology to support this type of learning. An example of research in Category 2: Affordances is the study conducted by Lai, Yang, Chen, Ho, and Chan (2007). In the experimental study of Lai et al., they found that mobile technologies are effective in improving 5th graders' knowledge creation during experiential learning on a field trip exploring plants. The students with Personal Digital Assistant (PDA) outperformed students without PDA as they were supported to recognize and utilize the capabilities (such as photo-taking and sound recording) afforded by the mobile technologies. For example, students with PDAs could record plant information quickly by taking photos, compare multiple photos to examine different parts of a plant, and save and magnify a photo to examine a specific part of a plant more closely at a later time. Lai et al. also cautioned about early introduction of mobile technologies in experiential learning as that could make learners rely on mobile technology affordances (e.g., photo-taking) rather than utilizing their own ability (e.g., observation in the context of experiential learning).

Table 4:
Affordances

Expert-generated statements	*Ratings of importance, frequency*					
Research in:	1	2	3	4	5	*Mdn (IQR)*
Affordances of mobile technology to support problem representation and problem solving	0	0	3	7	4	4.0 (0.8)
Affordances of mobile technology to support knowledge construction and collaborative learning	0	1	1	7	5	4.0 (1.0)
Identifying clear, contextualized learning needs that mobile learning technologies and services could address	0	0	1	4	9	5.0 (1.0)

Note: A rating of 1 equals 'No Importance' and 5 equals 'Very High Importance'.
IQR, interquartile range.

Research Priority Category 3: Theory (4 Statements)

Despite the fast-paced growing literature in the field of mobile learning (Kukulska-Hulme & Traxler, 2007) and the availability of mobile learning models (e.g., Koole, 2009; Park, 2011), experts still seem to recognize the needs for theoretical framework to guide the design and research of mobile learning by factoring in culture, context, ubiquitous learning and/or constructivist learning. Koole's (2009) Framework for the Rational Analysis of Mobile Education (FRAME) model builds on the intersection of three fundamental aspects—device, learner, and social that allow educators to consider the overlapping aspects when designing mobile learning. These intersected aspects include device usability (i.e., device + learner), social technology (i.e., device + social), and interaction learning (i.e., learner + social). Finally, mobile learning is at the confluence of the device, learner, and social aspects. The FRAME model provides an intuitive way for considering and designing mobile learning activities.

Park (2011) adopted Transactional Distance theory to create a pedagogical framework for mobile learning. Park's framework categorized mobile learning into four types after analyzing the literature: 1) high transactional distance socialized m-learning, 2) high transactional distance individualized m-learning, 3) low transactional distance socialized m-learning, and 4) low transactional distance individualized m-learning—all mediated by mobile devices. The goal of this framework is to help instructional designers of open and distance learning to factor in the extent of psychological separation between the learner and the instructor as well as the levels of social/individual activities when designing mobile learning in their contexts.

There are also other frameworks or models on different aspects of mobile learning, such as the 3-level evaluation framework of mobile learning proposed by Vavoula and Sharples (2009) (see Research category 5: Evaluation/assessment), the self-regulated learning model of mobile learning proposed by Sha, Looi, Chen, and Zhang (2011) (see Research priority category 6: Learners), and the design requirements framework for mobile learning environments by Parsons, Ryu, and Crashaw (2007) (see Research priority category 7: Mobile technologies and interface design). With the Theory category ranked high (No.3) by the experts, it appears that the expert panelists do not consider current models as sufficient for designing mobile learning in various contexts. Table 5 lists the four recommendations generated by the experts.

Table 5:
Theory

Expert-generated statements	*Ratings of importance, frequency*					
Research in:	1	2	3	4	5	*Mdn (IQR)*
Pedagogical framework for the use of mobile device for constructivist learning	0	1	2	10	1	4.0 (0.0)
Theoretical/conceptual framework to guide the design of mobile learning	0	0	0	9	5	4.0 (1.0)
Developing sound, culturally and contextually sensitive theories of learning for a mobile world	0	0	2	12	0	4.0 (0.0)
New pedagogical theories for context-aware ubiquitous learning environments	1	0	1	12	0	4.0 (0.0)

Note: A rating of 1 equals 'No Importance' and 5 equals 'Very High Importance'.
IQR, interquartile range.

Research Priority Category 4: Settings For Learning (6 Statements)

Settings for learning here refer to a variety of aspects, including level of education (e.g., tertiary education), delivery mode and environment (e.g., online, blended, traditional/classroom), and format and structure of education (formal vs. informal). An example of research under this category is Jones, Scanlon, and Clough (2013). Jones et al. compared and contrasted two case studies regarding the dimensions of learner control, location of learning, and the different support mechanisms for inquiry learning in informal settings. In the second case study, adult learners used mobile devices to engage in geocaching to learn about landscape. Jones et al. also proposed a framework for considering the aforementioned dimensions when developing mobile learning for informal settings. As seen in Table 6, the Delphi experts suggested a total of six research needs addressing mobile learning in various settings. As Wu et al. (2012) suggested in their review of 164 articles on mobile learning, 51.98% of research published between 2003 and 2010 focused on higher education, and yet *application in tertiary education* is still considered important in Category 4. However, future research might want to consider conducting research at other levels (e.g., secondary education) to help fill the gap in research and contribute to the field.

Table 6:
Settings for Learning

Expert-generated statements	*Ratings of importance, frequency*					
Research in:	1	2	3	4	5	*Mdn (IQR)*
Application in tertiary education	0	2	6	5	1	3.0 (1.0)
Smartphone technologies in the classroom	2	0	4	6	2	4.0 (1.0)
Embedding mobile learning into day-to-day teaching	0	1	3	6	4	4.0 (1.5)
Implementing mobile learning in a blended delivery mode of education	0	0	4	7	3	4.0 (0.8)
Variations in student outcomes between online and traditional education	2	1	6	2	3	3.0 (1.0)
Addressing how to bridge the gap between informal socialized learning and formal institutionalized learning, and the role that mobile learning might take in this	0	2	3	4	5	4.0 (2.0)

Note: A rating of 1 equals 'No Importance' and 5 equals 'Very High Importance'.
IQR, interquartile range.

Research Priority Category 5: Evaluation/Assessment (2 Statements)

The two statements included in the evaluation/assessment research category, shown in Table 7, recommended research focus on developing methods for evaluating mobile learning in general. Experts also recognized the capability and potential of mobile technologies that lead to the context-aware ubiquitous mobile learning, and suggested developing strategies to assess mobile learning along those aspects. While there is little research on the methods and strategies of assessing mobile learning, there have been efforts in developing framework for evaluating mobile learning. For example, Vavloula and Sharples (2009) proposed a 3-level framework consisting of *usability* (micro level), *learning experience* (meso level), and *integration within existing educational and organizational contexts* (macro level). They proposed to use this 3-level framework to address the challenges of evaluating mobile learning. Those challenges include: 1) capturing and analyzing learning in context and across contexts; 2) measuring mobile learning processes and outcomes; 3) respecting learner/participant privacy; 4) assessing mobile technology utility and usability; 5) considering the wider organizational and socio-cultural context of learning; 6) and assessing in/formality. The proposed framework and challenges provide good foundations for future research in developing and testing methods and strategies for evaluating mobile learning.

From a different perspective, mobile technologies can be used to support assessment process and assessment can be considered a type of learning and teaching strategy. Nikou & Anatasios (2013) discussed mobile-device-based assessment such as classroom response systems (e.g., Clickers or other voting apps on mobile devices), self-assessment, peer assessment, collaborative assessment, computerized adaptive testing on mobile devices, dynamic assessment, context-aware and location-aware assessment. When (formative) assessment is integrated into the instruction as part of students' learning process by checking learners' understanding and providing feedback, mobile assessment can serve as a variation of mobile learning which also deserves research attention.

Table 7:
Evaluation/Assessment

Expert-generated statements	*Ratings of importance, frequency*					
Research in:	1	2	3	4	5	*Mdn (IQR)*
Developing robust and appropriate methods to evaluate mobile learning	0	0	0	5	9	5.0 (1.0)
Assessment strategies for context-aware ubiquitous learning	0	0	3	7	4	4.0 (0.8)

Note: A rating of 1 equals 'No Importance' and 5 equals 'Very High Importance'.
IQR, interquartile range.

Research Priority Category 6: Learners (4 Statements)

Within the Learners research category, there are four statements as listed in Table 8. The Delphi experts valued researching how one's self-directed learning capability affects mobile learning, with ten experts rating the statement 4 and one rating it 5. The statement, "psychological factors related to context-aware ubiquitous learning" also has the majority of experts rating it 4 but it was not as valued as the statement above. There is little research examining how self-directed learning capability can affect mobile learning or how to use mobile technology to support self-directed learning (SDL). However, one study by Sha, Looi, Chen, and Zhang (2011) examined the conceptual and theoretical connections between mobile learning and self-regulated learning (SRL). SRL is very often used interchangeably with SDL, except that SDL is often used in discussing web-based learning without instructors (Bracey, 2010). Sha et al. proposed an analytic SRL model as a conceptual framework for understanding mobile learning. They argued that in mobile learning learners need to assume the responsibility of their own learning, more so than in other types of learning, due to ubiquity afforded by mobile technologies. This need for learner responsibility makes self-regulated learning perspectives especially meaningful and important. In their model, self-regulation serves as the agency of learning that is mediated by mobile devices, whereas mobile devices (technologies) serve as social, cognitive, and metacognitive tools that can provide social and pedagogical supports for learner autonomy in the mobile learning processes.

Table 8:
Learners

Expert-generated statements	*Ratings of importance, frequency*					
Research in:	1	2	3	4	5	*Mdn (IQR)*
Cognitive variations in the Millennial Generation	1	5	5	3	0	3.0 (1.0)
How self-directed learning capability affects mobile learning	0	1	2	10	1	4.0 (0.0)
Meeting the learning needs of the newer generations of learners with mobile learning since they are comfortable using mobile technology	1	3	6	3	1	3.0 (1.5)
Psychological factors related to context-aware ubiquitous learning	0	0	5	8	1	4.0 (1.0)

Note: A rating of 1 equals 'No Importance' and 5 equals 'Very High Importance'.
IQR, interquartile range.

Research Priority Category 7: Mobile Technologies and Interface Design (4 Statements)

In this category (See Table 9), the experts identified the need in studying theory-based mobile system design and interface design for navigation/ease of use. The experts also consider that it is important to research mobile learning which incorporates Web 2.0 applications that foster collaboration, sharing, and creation with theoretical underpinnings of distributed cognition, sociocultural theory, and situated cognition (Hsu et al., 2014). Clinical decision support tools were also valued, but not as much as other research statements, perhaps due to the specificity. Parsons, Ryu, and Cranshaw (2007) proposed a design requirements framework for mobile learning environments. They utilized the elements in their model as criteria to examine four mobile learning projects, exemplifying how to use the model for analyzing and designing mobile learning environments and systems. Their model factored in four perspectives, including generic mobile environment issues (e.g., mobile interface design), learning contexts, learning experiences, and learning objectives. This model also incorporated the interaction dimension that looks into the different needs under individual learning and collective learning. The study by Parsons et al. provided a good example of research needed in this category and a potential framework for research on *developing new mobile learning technologies and systems*.

Table 9:
Mobile Technologies and Interface Design

Expert-generated statements	*Ratings of importance, frequency*					
Research in:	1	2	3	4	5	*Mdn (IQR)*
Web 2.0 mobile learning	0	0	6	8	0	4.0 (1.0)
Clinical decision support tools in appropriate disciplines	0	2	5	5	2	3.5 (1.0)
Developing new mobile learning technologies and systems based on sound theory and analysis of mobilized learners	0	1	2	9	2	4.0 (0.0)
Effective interface for mobile learning so that all learners can successfully learn using mobile technology	0	0	3	7	4	4.0 (0.8)

Note: A rating of 1 equals 'No Importance' and 5 equals 'Very High Importance'.
IQR, interquartile range.

Research Priority Category 8: Context Awareness and Augmented Reality (6 Statements)

Experts recommended research in context-aware ubiquitous learning in general as seen in the statements listed in Table 10. One expert, particularly, focused on a few more specific statements on mobile augmented reality learning experiences in science, for collaborative problem solving, engagement, and learning gains. It is worth noting that context-aware ubiquitous learning also appears in other priority categories (e.g., 1, 3, 5) with various emphases including teaching and learning strategies, theory, and assessment, arguably due to the mobile devices' affordances of ubiquity.

The study by Shih, Chu, Hwang, and Kinshuk (2011) provides an example of research on context-aware ubiquitous learning. Shih et al. investigated the attitudes of 5th graders and their teachers about participating in a context-aware ubiquitous learning activity (supported by wireless, mobile, and context-aware technologies) regarding campus vegetation. They found students had significantly positive changes in attitudes toward mobile ubiquitous learning. They also found that class management became easier for the teacher even when students were learning outdoors, as the students focused on the learning content presented on the mobile devices. Teachers were also able to better monitor individual progress and provide individual advice without constant need of directing students' attention to learning tasks while in the field.

In terms of research in mobile augmented reality, Dunleavy, Dede, and Mitchell (2009) investigated and discussed the affordances and limitations of mobile augmented reality learning that situated learners in a physical environment with the support of real-time immersive participatory simulations on mobile devices. According to Dunleavy et al., while students and their teachers considered the learning experiences that involved technology-mediated narrative and interactive situated collaborative problem solving highly engaging, some students felt overwhelmed by the complexity of the activities. Their study presented the potential of mobile augmented reality for learning and the challenges to be addressed through further research and design.

Table 10:
Context Awareness and Augmented Reality

Expert-generated statements	*Ratings of importance, frequency*					
Research in:	1	2	3	4	5	*Mdn (IQR)*
Context-aware ubiquitous learning	0	0	2	5	7	4.5 (1.0)
Adaptive mobile learning	0	0	4	8	2	4.0 (0.8)
To what extent can mobile augmented reality experiences replicate authentic practices in high-need science-based or inquiry-based fields?	0	0	6	7	1	4.0 (1.0)
To what extent can mobile augmented reality experiences replicate, guide, and scaffold collaborative problem solving in physical environments?	0	0	7	4	3	3.5 (1.0)
What mobile augmented reality design strategies and techniques foster an effective blend of narrative, content delivery, instruction, problem solving, and game mechanics as measured by engagement?	0	0	5	7	2	4.0 (1.0)
Do students immersed in mobile augmented reality experiences have greater learning gains on measures of science content and scientific inquiry process skills than students who are immersed in a similar paper-based control simulation?	1	1	4	7	1	4.0 (1.0)

Note: A rating of 1 equals 'No Importance' and 5 equals 'Very High Importance'.
IQR, interquartile range.

Research Priority Category 9: Infrastructure and Management (2 Statements)

This priority category identified by the Delphi experts involved the "enabler" of mobile learning, including infrastructure and management. As seen in Table 11, the experts saw a need to examine the necessary facilities and physical settings (i.e., infrastructure) for mobile learning to occur and be sustained. There is little academic research in this category, probably due to its practical nature, leaning more toward strategic planning and implementation at the institutional level. However, the importance of this category should not be ignored. Cobcroft, Towers, Smith, and Axel (2006) identified opportunities and challenges brought forth by mobile learning through a literature review. They pointed out that institutions need to carefully consider wireless infrastructure, the stability of overall learning management system (LMS), and the capability of

LMS for cross-platform delivery of mobile learning. As this category still lacks research, future exploration could help fill the void in the literature and contribute to our understanding of various aspects of infrastructure and management that could enable mobile learning.

Table 11:
Infrastructure and Management

Expert-generated statements	*Ratings of importance, frequency*					
Research in:	1	2	3	4	5	*Mdn (IQR)*
Infrastructure required for implementing mobile learning	0	0	4	6	4	4.0 (1.5)
Management of mobile learning projects	0	1	4	5	4	4.0 (1.8)

Note: A rating of 1 equals 'No Importance' and 5 equals 'Very High Importance'.
IQR, interquartile range.

Research Priority Category 10: Country and Digital Divide (3 Statements)

The last priority category identified by the Delphi experts involved researching the potential digital divide regarding mobile learning from different aspects (see Table 12). It addressed how mobile learning can benefit developing countries (i.e., mobile learning as solutions for education), how mobile learning is implemented in the most populated country (i.e., status report and case studies), and how to reduce digital divide in deploying mobile learning (i.e., solving digital divide to make mobile learning possible). Mobile learning has been primarily developed in Europe, the U.S., and some eastern Asian countries where there are continuous, and significant investment and rapid advancement in technology (Traxler & Kukulska-Hulme, 2005). Due to different (e.g., lower) levels of investment and advancement, mobile technologies and mobile learning can look very differently in practice and require appropriate adaptions in design for contextual needs. For example, Traxler and Dearden (2005) examined and evaluated the efficiencies, cost, and alternatives associated with using Short Message Service (SMS) to deliver learning content and study-guide materials with a goal of training 200,000 in-service teachers in Kenya (Sub-Saharan Africa). Traxler et al. found SMS has great potential for the Kenyan school system considering Kenya's infrastructure, such as poor landline phone network, lively and energetic mobile phone networks, high mobile phone ownership and little or no Internet bandwidth outside of major cities.

Table 12:
Country and Digital Divide

Expert-generated statements	*Ratings of importance, frequency*					
Research in:	1	2	3	4	5	*Mdn (IQR)*
How mobile learning can benefit developing countries	0	1	4	3	6	4.0 (2.0)
Mobile learning in China's basic education	2	4	6	0	2	3.0 (1.0)
Endeavoring to reduce digital divides in the deployment of mobile learning solutions	0	1	7	3	3	3.0 (1.0)

Note: A rating of 1 equals 'No Importance' and 5 equals 'Very High Importance'.
IQR, interquartile range.

Discussions and Conclusions

When comparing our research findings and the research foci identified in the content analysis study of Hwang and Tsai (2011), it appears that motivation and perceptions and attitudes of mobile learning that were highly researched between 2001 and 2010, were not considered as part of the Top 10 categories by our panel experts. However, ubiquitous learning is still considered important as it appears in a few categories ranked important by our panel of experts, Teaching and Learning Strategies (Category 1), Theory (Category 3), Evaluation/Assessment (Category 5), Learners (Category 6), Context Awareness and Augmented Reality (Category 8). The study using text-mining method by Hung and Zhang (2012) and the study using content analysis method by Wu at al. (2012) both found that past research focused on effectiveness of mobile learning and the design of mobile learning systems. The effectiveness of mobile learning can be researched in various directions and contexts. Considering the research category identified in this current study, the effectiveness of mobile learning can mean researching under categories such as Teaching and Learning Strategies (Category 1), Affordances (Category 2), Settings for Learning (Category 4), and Context Awareness and Augmented Reality (Category 8). Also, the design of mobile learning systems is still considered important by our panel of experts as that research focus aligns well with categories such as Mobile Technologies and Interface design (Category 7), and Context Awareness and Augmented Reality (Category 8). As our discussions of the alignment between past research and the findings of this current study have revealed, there are still many unchartered areas and unanswered questions in mobile learning research, such as Infrastructure and Management (Category 9) and Country and Digital Divide (Category 10).

With the advancement in mobile technologies, proliferation of mobile devices, and mobile applications, mobile learning has garnered noticeable interest among educators and learning material developers. Also, research in mobile learning has gained great momentum in recent years. As it is an unfruitful task to identify isolated points of view that may lead to partial opinions, this Delphi study was designed to solicit the collective insight from scholars who make up some of the most prolific authors in mobile learning research. Participants responded to the question, "What should be the research priorities for the field of mobile learning over the next 5 years?" The collection of 40 consolidated statements and ten priority categories, produced and ranked by the panel of participating experts, provide an answer to this question. The contribution of this study is in defining directions for future research in mobile learning. Each of the 40 statements produced by the panel of experts offers a starting point that researchers may use to plan new studies or establish research agenda in mobile learning. The ten research priority categories, ranked by importance, align with existing discourse from researchers who have already turned their attention to various aspects of mobile learning research. Due to the practical value and potential of mobile technologies, the top-ranked priorities are related to the "how-to" of mobile learning (i.e., strategies) and "what it allows learners to do" (i.e., affordances). In addition, theory is emphasized (ranked 3rd in research categories) for its importance in supporting the design of mobile learning and teaching strategies when considering pedagogies and technology affordances.

The authors identify with the definition of mobile learning by O'Malley et al. (2005), and believe that mobile learning research should focus on learners and how to help them learn, and at the same time acknowledge the importance of affordances (i.e., what the technologies allow learners to achieve) that interface between learners and learning technologies. Our research findings help reinforce this line of thinking, enrich the definition of mobile learning through the collective experts' ideas, and provide prioritized categories, statements, and concrete examples for future research efforts.

Limitations and Future Research

While our study involved a representative international panel of experts, one limitation of our study is that not all of the 59 experts we identified could participate in our research. Also, some arguably important areas such as privacy and ethics in mobile learning practice have not made the Top 10 research categories. To amend the limitations, we provided the demographics of the expert panel so that readers can contextualize the findings of this study when reviewing this paper. Also, in the Acknowledgement section below, we listed the experts who are willing to be recognized to provide credibility and contextualize their consensus. In addition to pursuing the research directions identified by the panel experts in this study, future research could examine the most recent studies on mobile learning, and evaluate if the most recent studies and the suggested future research directions in those studies fall into the categories identified in this current Delphi study.

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