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A Review of Models and Frameworks for Designing Mobile Learning Experiences and Environments

Un examen des modèles et cadres de travail pour la conception d'expériences et d'environnements d'apprentissage mobile

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Abstract

Mobile learning has become increasingly popular in the past decade due to the unprecedented technological affordances achieved through the advancement of mobile computing, which makes ubiquitous and situated learning possible. At the same time, there have been research and implementation projects whose efforts centered on developing mobile learning experiences for various learners' profiles, accompanied by the development of models and frameworks for designing mobile learning experiences. This paper focuses on categorizing and synthesizing models and frameworks targeted specifically on mobile learning. A total of 17 papers were reviewed, and the models or frameworks were divided into five categories and discussed: 1) pedagogies and learning environment design; 2) platform/system design; 3) technology acceptance; 4) evaluation; and 5) psychological construct. This paper provides a review and synthesis of the models/frameworks. The categorization and analysis can also help inform evaluation, design, and development of curriculum and environments for meaningful mobile learning experiences for learners of various demographics.

Résumé

Au cours de la dernière décennie, l'apprentissage mobile est devenu de plus en plus populaire grâce à la facilité d'accès sans précédent à la technologie qu'ont permis les progrès de l'informatique mobile, ce qui rend possible l'apprentissage ubiquiste et contextualisé. En même temps, des projets de recherche et de mise en œuvre ont été réalisés, dont les efforts étaient axés sur le développement d'expériences d'apprentissage mobile pour des apprenants de différents profils et qui s'accompagnaient de l'élaboration de modèles et de cadres de travail pour la conception d'expériences d'apprentissage mobile. Cet article met l'accent sur la catégorisation et la synthèse de modèles et de cadres ciblant précisément l'apprentissage mobile. En tout, 17 articles ont été examinés, et les modèles ou cadres de travail ont été divisés en cinq catégories et fait l'objet d'une discussion : 1) conception de pédagogies et d'environnements d'apprentissage;

2) conception de plateforme/système; 3) acceptation de la technologie; 4) évaluation et 5) concept psychologique. Cet article offre un examen et une synthèse des modèles/cadres. La catégorisation et l'analyse peuvent également contribuer à informer l'évaluation, la conception et le développement de programmes et d'environnements pour des expériences significatives d'apprentissage mobile pour les apprenants de différentes origines démographiques.

Introduction

In the past decade, we have seen increasing sales of mobile devices (Gartner, 2011), rapid advancement in mobile technologies and features (Wu et al., 2012), and growing availability of various mobile applications (Hsu, Rice, & Dawley, 2012). Gartner (2014) expected the sales of mobile phones to reach 1.9 billion units in 2014, a 3.1% increase from 2013. Gartner (2014) also estimated that smartphone sales would represent 88% of global mobile phone sales by 2018 — a 66% increase from 2014. Mobile technologies have significant interconnected affordances including portability, Internet connectivity, and strong computing power (Hsu & Ching, 2013b). Together, these affordances allow mobile technologies to create great opportunities for flexible and ubiquitous learning (Hwang, Tsai, & Yang, 2008; Looi & Toh, 2014). In recent years, there has been increasing interest in the educational use of mobile devices/technologies (Rushby, 2012) and significant productivity in mobile learning research (Kukulska-Hulme & Traxler, 2007). In April 2015, our search with the keywords *mobile learning* in the EBSCO*host* databases led to 1,282 records of articles published between 2008 and 2015 in academic journals, compared to 129 records of articles published between 2000 and 2007 in academic journals — a 994% increase. Among the increasing volume of literature, there are great efforts in developing models and frameworks for designing mobile learning experiences and environments (e.g., Koole, 2009; Vavoula & Sharples, 2009). The developments mentioned above in turn lead to an emerging body of literature starting to identify trends in mobile learning research using methods such as content analysis (e.g., Hwang & Tsai, 2011; Wu et al., 2012) and text mining (e.g., Hung & Zhang, 2012). These reviews of literature examined published articles in journals and proceedings to identify research themes and increasing/decreasing trends based on researchers' analysis and interpretation. However, there is little, if any, review research analyzing and synthesizing existing models and frameworks for designing mobile learning experiences and environments. Frameworks delineate the conceptual relationships among components and hypotheses grounded in related theories, while models provide descriptive or prescriptive representation of relationships among components in a framework based on analysis of empirical evidence. In their research, Hsu, Ching, and Snelson (2014) reported ten areas of research in mobile learning that should receive attention and have high priority in the next five years, based on the consensus of a panel of international experts of mobile learning. These experts indicated that while there are increasing models and frameworks in mobile learning, more research effort is needed because conceptual and theoretical guidance can help support design and research in mobile learning. The purpose of this current paper is to categorize and synthesize existing mobile learning models and frameworks. This topic is important because a systematic analysis can help generate useful suggestions and insightful implications for educators, researchers, instructional designers, and developers who are interested in providing meaningful mobile learning experiences and environments based on sound theoretical foundations. It can also help identify gaps in the existing literature and provide future research directions in mobile learning.

Learning Experiences Afforded by Mobile Technologies

The affordances of mobile technologies make it possible for various learning to occur in a real-world context relevant to learners. Learners can take mobile devices anywhere they want to execute tasks or continue their learning beyond the classroom. Learning can be ubiquitous and seamless because of the portability and strong computing power of mobile technologies (Liu, Tan, & Chu, 2009). Mobile devices afford rich and varied communication and collaboration possibilities (Motiwalla, 2007) that are critical to collaborative knowledge construction. By sharing knowledge and experiences, learners can develop expertise related to their field or their interests (Lave & Wenger, 1991). In the following sections, we synthesize and discuss various possible learning experiences that can be supported and enhanced by integrating mobile technologies. The discussions below will help demonstrate the rich possibilities of applying mobile technologies to learning, and highlight the need for models and frameworks that can guide the design and evaluation of mobile learning experiences.

Context-aware learning. Context-aware learning is a unique type of learning made possible by mobile technologies due to the capability of location-awareness, as a result of interaction among mobile device hardware such as GPS (global positioning system), Internet connection through wireless network or cellular network, and mobile apps. Even without GPS, current mobile apps or services like Google Maps can use wireless signals to triangulate the available data to estimate the mobile device holders' locations. This location-awareness feature provides many possibilities for context-aware learning. For example, context-relevant learning information such as weather conditions, historical sites information, or ecology systems can be automatically loaded on mobile devices. Learners will be notified based their locations and be able to access the information for analysis and learning in an authentic context (The New Media Consortium, 2004). An example of an extended application will be mobile augmented reality, where context-relevant information can be triggered and overlaid on the physical environments in which the learners are situated. An example of context-aware learning application is Wikitude (Marimom et al., 2010; "Wikitude," n.d.). This application leverages the GPS integrated in mobile devices to allow users to point their device in any direction, and presents virtual overlaid tags/markers on actual physical locations such as buildings, parks, stores, etc. on the device's screen. Users can then click on the virtual tags on the mobile device presented by Wikitude to access Wikipedia or other web resources to learn more about the locations of interests.

Seamless and ubiquitous learning. Due to the portability of today's mobile devices, learners can take learning on-the-go with their mobile devices. For example, during commuting, learners can use their mobile devices to search for information that was picked up during a conversation or taught in class, such as an economic crisis or the types of rock formations. Learners can also share and discuss design examples and ideas (e.g., Hsu & Ching, 2012) found in their immediate environments. Learning becomes seamless when mobile learning bridges the learning in-class (formal settings) and learning on-the-go (informal settings). Ubiquitous learning is closely related to and the logical extension of seamless learning. Ubiquitous learning means people can learn wherever and whenever they want to. When people can learn anywhere and at any time, learning is ubiquitous and seamless across environments and contexts (Hwang & Tsai, 2011).

Game-based learning. Game-based learning refers to learning in a gameplay context where learners solve problems that are presented in scenarios (Ebner & Holzinger, 2007). All the information and materials are situated and interwoven into game scenarios and there are usually storylines in which *learners as players* are presented with problems to solve. For example, Dunleavy, Dede, and Mitchell (2009) designed an augmented reality game that leveraged mobile technologies. They challenged middle and high school students in a gameplay that involves developing plans of action for encountering visitors from outer space. The students were organized in teams of four members, taking on one of the following roles: Chemist, cryptologist, computer hacker, and FBI (Federal Bureau of Investigation) agent. The teams were then tasked to collect evidence regarding the nature of the aliens who landed on earth, while competing with other teams in the context of gameplay to solve math, language arts, and scientific literacy problems.

Mobile computer-supported collaborated learning (mCSCL). mCSCL refers to learning activities that arrange students into pairs, groups, or communities in which the students work together to form questions, discuss ideas, explore solutions, complete tasks and reflect on their thinking and experiences (Laurillard, 2009; Stahl, Koschmann, & Suthers, 2006) by leveraging the affordances of mobile computing devices and technologies. After analyzing and synthesizing nine rigorous experimental and quasi-experimental studies, Hsu and Ching (2013a) categorized mCSCL interventions into four types: 1) presenting the individual portions of an assigned learning task and serving as the focal point of interaction; 2) facilitating communication and interaction; 3) providing feedback for group learning and instructor teaching; 4) managing and regulating interaction process.

Mobile social learning. Mobile social learning means learning that involves interacting with others in social networks by leveraging mobile apps and devices. Kabilan, Ahmad, and Abidin (2010) reported an example of social learning through their study on students using Facebook for language learning (writing). The students were positive overall about the experience and could tolerate mistakes and focus on gaining practice with the target language. However, some students did not consider it "serious" learning due to the media they used (not published books or articles) and the environments (not school). For similar contexts, mobile technologies can help further the social learning by building seamless and ubiquitous learning into social learning. Learners can interact with their social networks on the go, and share ideas as they appear instead of forgetting these ideas later. For example, Hsu and Ching (2012) integrated mobile devices and Twitter in an online course, where graduate students recorded, shared, critiqued, and discussed graphic design examples found in their daily lives. Students appreciated the social learning aspect that helped them connect with their peers, and valued the authentic examples to which the design principles were applied.

While mobile technologies can broaden the landscape of learning experiences, models and frameworks are critical in guiding the design, development, implementation, and evaluation of these mobile learning experiences. In this paper, we used the following method to help us categorize and synthesize mobile learning models and frameworks, generate suggestions, identify gaps in existing literature, and provide direction for future research.

Research Method

Data Sources and Article Selection Criteria

We conducted a search of article titles in databases including WorldCat, ERIC (Education Resources Information Center), and Google Scholar, using keyword combinations including: 1) ti: mobile learning and ti: model (where ti stands for title); 2) ti: mlearning ti: model; 3) ti: m-learning ti:model; 4) ti: mobile learning ti: framework; 5) ti: mlearning ti: framework; 6) ti: m-learning ti: framework. WorldCat is the World's largest online catalog and bibliographic database built and maintained by 72,000 participating libraries in 170 countries and territories ("WorldCat," n.d.). ERIC, sponsored by Institute of Educational Sciences and the United States Department of Education, provides online access to 1.5 million bibliographic records of journal articles and other educational materials ("Education resources information centre," n.d.). Google Scholar is a web-based search engine that indexes open-access academic publications and also provides access to most peer-reviewed journals published by the largest publishers in Europe and the U.S. ("Google scholar," n.d.; "Google scholar and academic libraries", n.d.). A search in these three databases allows the data collection to be comprehensive and inclusive. A total of 48 articles were located using the searching method described above. The first and the second authors reviewed the 48 articles and excluded from the final analysis the papers that were not refereed journal articles, such as proceedings or editor-reviewed papers. The focus of our study is on refereed articles, which helps ensure relative rigor and quality of data sources. Also, research papers that did not provide in-depth discussion of their proposed models or frameworks were excluded. Finally, some papers were excluded if they had heavy focus on technical system design (e.g., algorithms) instead of discussing the learning aspects based on empirical evidence or sound theories. We selected 16 articles from the original pool. We also included one influential book chapter by Koole (2009), whose FRAME model was cited in one of the refereed papers (i.e., Park, 2011) we analyzed in this study, and has been highly cited overall (159 times as of December 8, 2014). In total, 17 articles published between 2006 and 2013 were selected for review and analysis.

Data Analysis

The 17 articles were initially organized by the first author of this paper into categories based on their relevance and purpose. The second author then reviewed the categories and the articles associated with these categories. Next, both authors discussed the fit between articles and categories, and made necessary refinements of category names to ensure good representation of the associated articles. Each article was read thoroughly, and the models and frameworks were examined to ensure the existence of visual representations and in-depth discussion of the proposed models or frameworks. Table 1 presents the models and frameworks included and reviewed in this paper.

Table 1

A Categorization of Mobile Learning Models and Framework

Category (number of articles)	Year	Author	Article Title (hyperlinked)	Proposed Framework/Model
Pedagogies and Learning Environment Design (6)	2009	Koole	A model for framing mobile learning	The Framework for the Rational Analysis of Mobile Education (FRAME)
	2009	Peng, Su, Chou, & Tsai	Ubiquitous knowledge construction: Mobile learning re-defined and a conceptual framework	The Conceptual Framework of Ubiquitous Knowledge Construction
	2011	Park	A pedagogical framework for mobile learning: Categorizing educational applications of mobile technologies into four types	A Pedagogical Framework for Mobile Learning in Distance Education
	2012	Schmitz, Klemke, & Specht	Effects of mobile gaming patterns on learning outcomes: A literature review	A Framework of Analysis of Design Patterns for Mobile Learning Games
	2013	Abdullah, Hussin, Asra, & Zakaria	Mlearning scaffolding model for undergraduate English language learning: Bridging formal and informal learning	Mlearning Scaffolding Five-stage Model
	2013	Ng & Nicholas	A framework for sustainable mobile learning in schools	A Person-centered Sustainable Model for Mobile Learning
Platform/System Design (5)	2006	Taylor, Sharples, O'Malley, Vavoula, & Waycott	Towards a task model for mobile learning: A dialectical approach	Task Model for Mobile Learning
	2007	Motiwalla	Mobile learning: A framework and evaluation	An M-Learning Framework (for designing applications for collaborative learning)
	2007	Parsons, Ryu, & Cranshaw	A design requirements framework for mobile learning environments	A Framework for M-Learning Design Requirements
	2007	Uden	Activity theory for designing mobile learning	Using Activity Theory as a Framework for Designing Mobile Learning
	2007	Zurita & Nussbaum	A conceptual framework based on activity theory for mobile CSCL	The MCSCL Framework (based on Engestrom's Expanded Activity Theory Model)
Technology Acceptance (4)	2007	Huang, Lin, & Chuang	Elucidating user behavior of mobile learning: A perspective	An Extended Technology Acceptance Model (in the

Category (number of articles)	Year	Author	Article Title (hyperlinked)	Proposed Framework/Model
			of the extended technology acceptance model	context of mobile learning; adding perceived enjoyment and perceived mobility value)
	2010	Yau & Joy	Proposal of a mobile learning preferences model	A Mobile Learning Preferences Model
	2012	Chang, Yan, & Tseng	Perceived convenience in an extended technology acceptance model: Mobile technology and English learning for college students	An Extended Technology Acceptance Model (in the context of mobile learning; adding perceived convenience)
	2012	Park, Nam, & Cha	University students' behavioral intention to use mobile learning: Evaluating the technology acceptance model	A General Structural Model of Students' Acceptance of Mobile Learning
Evaluation (1)	2009	Vavoula & Sharples	Meeting the challenges in evaluating mobile learning: A 3-level evaluation framework	A 3-Level Evaluation Framework of Mobile Learning
Psychological Construct (1)	2012	Sha, Looi, Chen, & Zhang	Understanding mobile learning from the perspective of self-regulated learning	An Analytic Self-Regulated Learning (SRL) Model of Mobile Learning

Findings and Discussions

As models and frameworks usually integrate multiple aspects of concepts centered on a certain theme, the categorizations discussed here are not mutually exclusive. In this paper, the categories delineate the major aspect the models and frameworks were proposed for, and the categorization is not intended to serve as an absolute differentiation but to highlight the focus of each model or framework. For example, Uden's (2007) activity-theory-based framework for designing mobile learning focused on the components of a mobile activity system for the design of an enabled context-aware mobile learning application. While this framework explored how the various components (e.g., learners, activities, artifacts, etc.) interact with each other for context-aware learning (pedagogies), it is categorized under platform/system design for its technical emphasis and goals. In the following sections, we discuss each model or framework under the corresponding category, including 1) pedagogies and learning environment design; 2) platform/system design; 3) technology acceptance; 4) evaluation; and 5) psychological construct.

Pedagogies and Learning Environment Design

There are six papers proposing various models or frameworks that address pedagogies and learning environment designs. Among these six frameworks, Koole's (2009) framework is the most intuitive and easiest to apply. Koole's framework provides a practical checklist to assist educators when considering the foundational components and intersections of components of mobile learning when designing mlearning curricula.

Koole's (2009) Framework for the Rational Analysis of Mobile Education (FRAME) builds on the three respective fundamental components of mobile learning: *Device*, *learner*, and *social*. Koole indicated that the intersection of these aspects allows designers and educators to consider at a deeper level the implications of involving any two of these aspects when designing mobile learning. These intersected components 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 and concise way for considering and designing mobile learning activities.

Peng, Su, Chou, and Tsai (2009) proposed a conceptual framework of ubiquitous knowledge construction. Their framework is conceptually and visually hierarchical, with 1) the learners (i.e., mobile learners) and tools (i.e., ubiquitous computing) serving as the foundation; 2) moving up to the middle level of pedagogical methods with a focus on constructivism and lifelong learning; and 3) finally reaching the top level of a vision on achieving ubiquitous knowledge construction. Peng et al. also discussed the issues of ubiquitous learning that need to be addressed in order to achieve and scale up ubiquitous knowledge construction for mobile learning. This is important and practical for educators and designers to consider in promoting and implementing mobile learning. At the foundational level of learners and tools, the issues worth considering are the educational digital divide, classroom management, network literacy, and building partnerships for pedagogically sound educational tools. At the middle level of pedagogical methods, the issue lies in training teachers on cultivating constructivist learning and lifelong learning. At the top level of a vision of ubiquitous knowledge construction, the issues are about scaling up with the support of empirical evidence of effects of ubiquitous computing on learning.

By adopting transactional distance theory, Park (2011) created a pedagogical framework that categorized mobile learning into four types after analyzing the literature. The four types of mobile learning include: 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. These four types of mobile learning are all mediated by mobile devices. The goal of this framework is to help instructional designers of open and distance learning consider the extent of psychological separation between the learner and the instructor. According to this framework, the levels of social/individual activities should also be considered when designing mobile learning in these contexts.

Schmitz, Klemke, and Specht (2012) proposed a conceptual framework for analyzing mobile learning game design patterns and corresponding learning outcomes. The two major components that form their model are: 1) the game design patterns for mobile games established by Davidsson, Peitz, and Björk (2004); and 2) Bloom's (1956) taxonomy of learning outcomes that involves affective domain and cognitive domain for identifying educational objectives. Schmitz et al. used the conceptual model they proposed and defined (i.e., involving mobile game design patterns and Bloom's taxonomy of educational objectives) to analyze the mobile learning game studies they reviewed and categorized. They identified design patterns aligned with affective and/or cognitive learning outcomes. A total of 18 affective design patterns were identified to be associated with affective learning outcomes. Among the 18 patterns, eight were also associated with cognitive learning outcomes. These eight patterns included collaborative actions, cooperation, social interaction, competition, augmented reality, pervasive games, extra-game information, and role-playing. As demonstrated by Schmitz et al., their model can be used for analyzing mobile learning games to help inform design decisions regarding the design patterns aligned with desired affective and/or cognitive learning outcomes.

Abdullah, Hussin, Asra, and Zakaria (2013) proposed a framework with a focus on mobile language learning. Their goal is to allow students to take advantage of mobile technologies with the help of those who have more skills as a way to move from current knowledge/skill level to the next/higher level of knowledge/skills (i.e., Zone of Proximal Development (ZPD); Vygotsky, 1978). ZPD refers to the abstract distance between what a learner can do without help and what he/she can do with help, such as guidance from adults or collaborating with more capable peers (Vygotsky, 1978). The adapted framework proposed by Abdullah et al. (2013) includes five stages: 1) access and motivation; 2) network socialization; 3) information exchange; 4) context and knowledge construction; and 5) development. Abdullah et al. did not provide an innovative framework that is drastically different from the original model. Their framework's contribution lies in highlighting the unique aspects afforded by mobile technologies and mobile learning. These unique aspects are 1) network and connectivity among mobile devices, systems, applications, and people; and 2) mobility and the corresponding constantly changing learning contexts. The more capable others (adults or peers) can and should provide scaffolding to learners by taking advantage of these unique aspects of mobile technologies and mobile learning.

Ng and Nicholas (2013) proposed a person-centered framework for sustainable learning in schools. Their framework took a holistic view on how to ensure sustainable mobile learning practice by having the stakeholders work together under inclusive and communicative leadership. Among the stakeholders, Ng and Nicholas argued that teachers are central to the success and sustainability of mobile learning. The other important stakeholders include leadership and management (e.g., principals and mlearning coordinators), parents, students, technicians, and community (e.g., government bodies, software developers, researchers). The non-personal components include pedagogy, mobile devices (personal digital assistants, PDAs, in this case), infrastructure (e.g., wireless network), and the interactions among the stakeholders (e.g., training, communication, consultation, delegation etc.). Ng and Nicholas used this framework to examine the implementation of an mlearning program and the actions among stakeholders in an Australian school from 2007 to 2010. They argued that the following aspects need to be addressed for a successful and sustainable mobile learning program: First, it is important to develop positive attitudes in students and teachers toward the program by providing sufficient technologies (hardware and software) and technical support in real time. Second, it is important to ensure communication among stakeholders, especially regarding consultation and feedback to prevent rising tension and misunderstanding. Third, it is critical to delegate responsibilities with trust from management team to teachers, as well from teachers to their students. Trust will help members open up and be willing to communicate. Also, every stakeholder needs to develop a sense of ownership of the mobile learning program.

Platform/System Design

Five models/frameworks with the focus on platform/system design are discussed in this section—three of which were developed based on Engeström's (1987) activity system/theory. The models and frameworks categorized in this section can involve pedagogies and learning environment design. However, these five models and frameworks focus more on the technical aspects in general, compared to the models and frameworks discussed in the previous section.

This division corresponds to our earlier note that these models and frameworks are not mutually exclusive regarding categorizations and uses, but they do have emphasized perspectives that can be particularly useful for their targeted purposes in supporting the design for mobile learning.

Taylor, Sharples, O'Malley, and Vavoula (2006) proposed a task model for mobile learning. The task model synthesized theoretical approaches including socio-cultural theory (Vygotsky, 1978), activity system/theory (Engeström, 1987), and conversation theory (Pask, 1976). Taylor et al. also conducted field studies in the context of the large-scale MOBIlearn project based in Europe and used what they learned to inform the design of their model. The task model was mainly expanded from the activity system established by Engeström. The activity system was originally expanded from Vygotsky's formulations of the interplay among *subject*, *object*, and *tool* components to understand human activity and work practice. Engeström added three components—rules, community, and division of labor to help further explain activities occurring in an activity system. These components denote the situated dynamic social context in which activities happen. In the task model, Taylor et al. adapted Engeström's three components as *control* (previously rules), *context* (previously community), and *communication* (previously division of labor), which paves the way of adding layers of *spaces* to help capture the complicated dynamics of mobile learning activities. The contribution of the task model by Taylor et al. lies in adding the layers of technological space (e.g., communication protocol) and semiotic space (e.g., social rules) for each of the six components, and emphasizing the conversational/dialectical relationship between these two spaces under each component. The task model also includes examples of each component and the spaces in the context of mobile learning systems. This could be useful for designers and researchers aiming to evaluate, modify, or build mobile learning systems.

Motiwalla (2007) discussed his experience of transforming e-learning into mobile learning through leveraging wireless connectivity and handheld (mobile) devices. Motiwalla proposed a framework consisting of requirements that should be factored in when developing mobile applications to complement classroom or distance learning. He proposed a relatively simple framework to address the technical features that enable content delivery, personalization, and collaboration in mobile learning. On the dimension of content delivery, the pedagogical agents and mentors need to be able to *push* the learning materials or information to the learners. Also, the learners need to be able to *pull* the information they need (e.g., scheduling, grades, learning content, etc.) to their devices. On the other dimension, the mlearning system needs to be able to support both personalized learning (e.g., assignment due alerts) and collaborative learning (e.g., chat room, discussion board, instant messaging, etc.).

Parsons, Ryu, and Cranshaw (2007) proposed a design-requirements framework for mobile learning environments. Their model factored in four perspectives, including: 1) generic mobile environment issues (e.g., mobile interface design); 2) learning contexts; 3) learning experiences; and 4) learning objectives. This framework also incorporated the interaction dimension that looks into the different needs for individual learning and collective learning. Compared to the framework of Motiwalla (2007), the framework proposed by Parsons et al. was more sophisticated and comprehensive because it included and discussed more factors as well as the sub-components under each main factor for design consideration. Parsons et al. utilized the elements in their model as criteria to examine four implemented mobile learning projects. This also helped demonstrate how to use their framework to analyze and design mobile learning environments and systems.

Uden (2007) proposed a framework for a mobile application that supports context-aware and collaborative learning. This framework is based on Engeström's activity theory (AT) (1987). Uden argued that AT had advantages of supporting the design of mobile applications for learning because it recognized the importance of various components and the interaction of these components that make a (mobile) learning activity possible and successful. These include subjects (e.g., learners), objects (e.g., developed artifacts)/objectives (e.g., learning gain reflected through performance or test scores), and tools. The tools, such as computers or mobile devices, can help mediate the activities among subjects themselves (e.g., communication), and between subjects and objects (e.g., achieve desired learning outcomes). The subjects also directly interact with the tools through user-interface of the tools (e.g., mobile devices). It is worth noting that the tools are not limited to physical ones. Tools can also be less tangible yet very powerful, such as in the case of languages. With the emergence of computers and mobile technologies, the tools can actually be integrated (e.g., text and video chat/communication via mobile devices) and become even more powerful in mediating the interaction between subjects and objects to achieve desired outcomes, such as improved learning performance. Uden also argued for activity theory's alignment with context-aware learning afforded by mobile technologies because dynamic contexts (e.g., social, cultural, political, physical, etc.) are constantly involved in learning activities. Mobile technologies can serve as great tools for learning because learners are provided with the option of being mobile while having access to relevant contextual information as a result of the device portability and network connection.

Uden proposed that designing an activity-based mobile learning application should go through the following four major steps: 1) clarify the purpose of the activity; 2) analyze the context for learning and use; 3) historically analyze the activity and its constituent components and actions; 4) search for internal contradictions as the driving forces behind disturbances, innovations and change of activity system. The benefit of this design approach is that it takes a comprehensive view of the dynamic mobile learning activity and system as a whole. However, it also requires significant involvement of time and effort to research and validate the impact through stages and longitudinal tracking.

Zurita and Nussbaum (2007) proposed an mCSCL model based on expanded activity theory model. While they did not delve into activity theory model as deeply as Uden (2007), their model's contribution lies in: 1) focusing on collaborative learning using mobile devices; 2) adding layers with specific and encompassing components (e.g., social and technological) that connect different nodes proposed in Engeström's extended activity theory model, and can assist designers of mobile collaborative learning to consider the interactions of various aspects in the context of collaborative learning; 3) offering a six-step method for designing mCSCL activities and applications that can be mapped back to the mCSCL framework they proposed. The six steps are: 1) characterize collaborators; 2) define the group's educational objective; 3) establish the desired social interaction skills; 4) choose the type of collaborative learning activity (i.e., interchange, construction, and management); 5) define activity tasks; 6) define the roles and rules (i.e., social roles and rules; roles and rules supported by the technology).

Technology Acceptance

There are four papers proposing acceptance models regarding mobile learning and technologies, and three of them are based and expanded upon the technology acceptance model by Davis (1986, 1989, 1993; see also Huang et al., 2007, Figure 1; Chang, Yan, & Tseng 2012, Figure 1).

Yau and Joy (2010) proposed a mobile learning preferences (MLPs) model consisting of five contextual dimensions. Their proposed model is based on their previous work on context-aware mobile learning. They interviewed 37 university students in the United Kingdom and developed a personalized mlearning application to help students manage their mobile learning through scheduling and reminders (see Yau & Joy, 2009). At the time of proposing this MLPs model, they were conducting two studies to help validate this model. The five proposed dimensions derived from their analysis of the interview data, include: 1) location of study; 2) perceived level of distractions; 3) time of day; 4) motivation level of the learner; and 5) available time. These dimensions related to learners' preferences could potentially help capture the factors to be considered when designing context-aware mobile learning.

Huang, Lin, and Chuang (2007) conducted statistical analysis to develop a general structural model to verify whether their extended technology acceptance model (TAM) could be used to predict mobile learning acceptance at the higher education level. Huang et al. surveyed undergraduate and graduate students in two universities in Taiwan, and obtained a total of 313 sets of valid responses. In their extended TAM, they added two factors, *perceived enjoyment* and *perceived mobility value*. Through data analysis, they found that both factors were significant in explaining the acceptance of mobile learning. The contribution of this model lies in its focus on learning in the *mobile* context, and its verification of the importance of the affordance of mobility (portability) for learners to accept mobile technologies as tools for learning. The other added and significant factor, perceived enjoyment, also shows its importance in affecting learners' perceived ease of use and perceived usefulness of mlearning. Together these affect learners' attitude toward mlearning and learners' behavioral intention toward mlearning.

Similar to Huang et al. (2007), Park, Nam, and Cha (2012) did not develop a new conceptual model for technology acceptance per se, but conducted statistical analysis to develop a general structural model. They distributed questionnaires to students in a Korean university to collect data. Out of the 567 students who responded, Park et al. analyzed the data from 288 students who identified themselves as having used mobile devices. Their model verified the use of TAM to help explain and predict learners' acceptance of mobile learning at the university level. They identified several external latent factors that have direct or indirect effects on learners' behavioral intention of using mobile learning, including 1) mlearning self-efficacy; 2) major relevance; 3) system accessibility; and 4) subjective norm. Park et al. argued that social motivational theory could be used to justify the impact of these factors on university students' use of mobile learning.

Chang, Yan, and Tseng (2012) proposed another extended TAM by including *perceived convenience* as a predicting factor in mlearning acceptance. They conducted their study and developed their model in the context of college students' English language mobile learning. In their study, 158 students participated in mobile learning of the English language using personal digital assistants (PDAs), and responded to a survey that collected data on the added new variable *perceived convenience*, and other variables originally included in TAM, such as perceived usefulness, perceived ease of use, attitude toward using, and continuance intention (intention to use). Chang et al. found that perceived convenience, perceived ease of use and perceived usefulness were antecedent factors that affected acceptance of English mobile learning. They also found that perceived convenience, perceived ease of use and perceived usefulness had a significantly positive effect on attitude toward using. In addition, perceived usefulness and attitude toward using had a significantly positive effect on continuance of intention to use. Through these findings, they established a model that showed the impact of perceived convenience on continuance of intention to use mobile technology for learning English.

Evaluation

Similar to the scarce research on methods or strategies for evaluating mobile learning, there is little research on frameworks/models for evaluating mobile learning. Vavoula and Sharples (2009) argued that there are six types of challenges in evaluating mobile learning. These 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 informality and formality.

To address these challenges of evaluating mobile learning, Vavoula and Sharples proposed using a three-level framework consisting of *usability* (micro level), *learning experience* (meso level), and *integration within existing educational and organizational contexts* (macro level) through each of the three phases of mobile learning project development. At each phase, design, development, and deployment, the mobile learning project should be examined at each of these three levels. The proposed framework of intersected levels and phases, and identified challenges of evaluation provide solid foundation for future research in developing and testing methods and strategies for evaluating mobile learning.

Psychological Construct

Only one paper was found to specifically focus on psychological construct in the context of mobile learning. Sha, Looi, Chen, and Zhang (2012) discussed the important role of self-regulation in mobile learning. Sha et al. proposed an analytic self-regulated learning (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 the 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. In their paper, they also demonstrated how to analyze and interpret mobile learning through the lens of their SRL model by discussing a three-year project conducted in an elementary school science classes in Singapore.

Gaps in the Research: What Are We Missing?

There are various uses of game-based learning that involve mobile technologies, such as using mobile games for learning and game-based augmented reality (AR) (e.g., Dunleavy, Dede, & Mitchell, 2009; Kim, Buckner, Kim, Makany, & Teleja, 2012). However, there are no models or frameworks on using or designing game-based mobile augmented reality. One effort closest in this regard is Dunleavy's (2014) work on proposing three design principles for augmented reality learning, based on his own research and literature review in mobile technologies that can enable learners to interact with digital information embedded in the physical environment. The three principles are: 1) enable and then challenge (challenge); 2) drive by stories or narratives (fantasy); 3) and see the unseen (curiosity). While the proposed principles along with project examples provided in Dunleavy's paper can offer some initial guidelines for educators and designers interested in designing game-based AR learning experiences, a more comprehensive framework is needed to help conceptualize the design components, requirements, and challenges involving game-based mobile AR experiences.

In a recent study, Kim et al. (2012) reported the success of applying their game-based mobile learning approach in providing opportunities for children from marginalized communities in India. They found that children could familiarize themselves with the provided technologies, develop problem-solving abilities, and learn math through mobile games without much adult intervention. While Kim et al. claimed to have "a comparative analysis of a game-based mobile learning model in low socioeconomic communities" (p. 329), they did not use the data and experiences to construct a model or conceptual framework of game-based mobile learning that can be generalized or applied in other learning or design contexts.

In review of the study by Kim et al., another aspect worth noting is the lack of mobile learning models or frameworks that factor in the needs of developing countries in mobile learning. While the models and frameworks discussed in this paper certainly can be applied in developing countries, there is a lack of models and frameworks grounded in empirical research conducted in developing countries' contexts. This gap in research is understandable because research of mobile learning has started in developed countries (the mainstream) that have more resources in capital and infrastructure. Compared to the developing countries, the developed countries are also more advanced in investing in research and development in mobile technologies. This is unfortunate because developing countries, despite the lack of resources, can still benefit from mobile learning. For example, while Kenyans had a poor landline phone network, and little or no Internet bandwidth outside of major cities, they had lively and energetic mobile phone networks, and high mobile phone ownership. With appropriate design, researchers and educators could leverage available resources to support practical usage of short message service (SMS) to deliver training materials (Traxler & Dearden, 2005). The needs and challenges due to unique cultures, different level of infrastructure, and various views of what constitutes learning (Traxler, 2013) in developing countries should be valued and researched so learners can benefit from what mobile learning can offer.

In terms of technology acceptance models (TAM) in the context of mobile learning, based on the findings of Huang et al. (2007), Chang et al. (2012), and Park et al. (2012), the external variables that were added and hypothesized to have significant impact on learners' mobile learning acceptance in higher education. These variables are 1) *perceived enjoyment* and *perceived* *mobility value* (based on analysis of responses from 313 undergraduate and graduate students in Taiwan); 2) *mlearning self-efficacy*, *major relevance*, *system accessibility*, and *subjective norm* (based on analysis of responses from 288 university students in Korea); 3) *perceived convenience* (based on analysis of responses from 158 students in Taiwan in the context of English language learning). While these factors are significant in each model, it would be helpful for future research to incorporate all of these identified factors in one study to examine their impact on mobile learning acceptance. Also, these studies were conducted in two East Asian countries in higher education settings only, which could, to a degree, limit these models' generalizability. Future studies could consider: 1) replicating the past research in other geographical regions of the world (e.g., in European countries or the U.S. with rich resources in mobile infrastructure, and in other countries just starting to acquire mobile learning resources); 2) extending the verification of TAM model on mobile learning to K-12 settings.

Conclusion, Limitation, and Future Research

This review focuses on conceptual models and frameworks that can help guide mlearning research and design for mlearning experiences. These models and frameworks were divided into the following categories: pedagogies and learning environment design, platform/system design, technology acceptance, evaluation, and psychological construct. Technical articles on mobile learning system design architecture that discuss data transfer, algorithm, optimizing intelligent system's operation, etc. (e.g., Al-Hmouz, Shen, Al-Hmouz, & Yan, 2012), while important for the field of study, were not included in this review. There was some previous effort for reviewing mobile learning models proposed in past research (e.g., Udanor & Nwodoh, 2010), but the method of selection and review was not clear and the number of models included was limited. Considering the fast development of mobile technologies and mobile learning, a more updated review on mobile learning system architecture would benefit learners, educators, designers, and researchers. Future research can consider systematically analyzing and synthesizing this area of research to provide insight on the models/frameworks of technical development of mobile learning applications and systems. We also recognize there are some existing models and frameworks (e.g., de Freitas & Oliver, 2006; Luckin, 2008), while not originally or specifically proposed for mobile learning, might be adopted for the design of mobile learning. In addition, there are models and frameworks related to mobile learning published in other venues such as book chapters or conference proceedings that could be useful to researchers and practitioners (e.g., Muyinda, Lubega, Lynch, & van der Weide, 2011). Future research efforts could be directed toward examining the aforementioned contributions/areas as well, which will complement this review and provide a more comprehensive picture of the landscape of models and frameworks for mobile learning design and research.

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