Mobile learning: A framework and evaluation

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Abstract

Wireless data communications in form of Short Message Service (SMS) and Wireless Access Protocols (WAP) browsers have gained global popularity, yet, not much has been done to extend the usage of these devices in electronic learning (e-learning). This project explores the extension of e-learning into wireless/handheld (W/H) computing devices with the help of a mobile learning (m-learning) framework. This framework provides the requirements to develop m-learning applications that can be used to complement classroom or distance learning. A prototype application was developed to link W/H devices to three course websites. The m-learning applications were pilot-tested for two semesters with a total of 63 students from undergraduate and graduate courses at our university. The students used the m-learning environment with a variety of W/H devices and reported their experiences through a survey and interviews at the end of the semester. The results from this exploratory study provide a better understanding on the role of mobile technology in higher education.
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1. Introduction

A survey on US mobile industry found that mobile device sales grew by 40% between 2002 and 2003, and predicted that PDA/mobile phone sales will outstrip PC sales by 2005 with the majority

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of companies switching to wireless networks by 2008 (Ellis, 2003). Computing devices have become ubiquitous on today's college campuses. From notebook computers to Wireless phones and Handheld devices[1] (or W/H devices for short), the massive infusion of computing devices and rapidly improving Internet capabilities have altered the nature of higher education (Green, 2000). Computer Assisted Learning (CAL) has proliferated tremendously in the last few decades with the use of Internet, email, multimedia technology, and intelligent tutoring system on campus. A 2000 Campus Computing Survey revealed that the majority of college professors use email to communicate with their students, and approximately one-third of college courses utilize CAL technology (Green, 1999). Similarly, Jones (2002) reports that a great majority of college students own computers and wireless devices with almost 80 percent believing that Internet use has enhanced their learning experience.

Despite the tremendous growth and potential of the W/H devices and networks, wireless e-learning and mobile learning (m-learning) is still in its infancy and in an embryonic stage. *m-learning* intersects mobile computing with e-learning; it combines individualized (or personal) learning with anytime and anywhere learning (Quinn, 2001). It is facilitated by a convergence of Internet, wireless networks, W/H devices and e-learning. With a W/H device, the relationship between the device and its owner becomes one-to-one, always on, always there, location aware, and personalized (Homan & Wood, 2003). The place independence of W/H devices provides several benefits for e-learning environment like allowing students and instructors to utilize their spare time while traveling in a train or bus to finish their homework or lesson preparation (Virvou & Alepis, 2005). Similar arguments have been made in the business world on how a W/H device can improve time-management efficiency by converting worker dead-time into a productive activity (BenMoussa, 2003). The key features of using a W/H device for e-learning are its' personalization capability and extended reach; this has potentially attracted more and more learners, especially adult learners, for whom the work-life balance is critical. W/H devices have the potential to change the way students behave and interact with each other. A typical scenario is that of a learner who is enrolled in an e-learning class for MBA program. While waiting for her flight at an airport, she can access class materials or interact with her classmates and instructors or download an assignment via her wireless PDA device. According to Robert Meinhardt, AvantGo's VP of Enterprise Marketing *"Wireless [access] is an important key to e-learning [as] it takes e-learning to the field, where the best hands-on learning takes place."* (Setaro, 2001).

This research explores the integration of mobile technology in distance learning or traditional classroom environments. Specifically, it investigates the usage of W/H devices such as PDAs and Smart phones for data services like Wireless Access Protocols (WAP), Short Message Service (SMS) and Wireless Markup Language (WML) in higher education. The WAP protocol has gained global popularity for data services because of its thin-client architecture and device independence. The thin-client architecture allows applications to run on the server and transported to W/H devices thereby removing the need for sophisticated client device. Despite W/H device popularity with students, not much has been done to extend e-learning to these devices.

Learning on W/H devices will never replace classroom or other electronic learning approaches. However, if leveraged properly, mobile technology can complement and add value to the existing

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[1] Like Personal Digital Assistant (PDA) or Smart Phones which hybrid mobile and handheld device into one device.

learning models like the *social constructive theory* of learning with technology (Brown & Campione, 1996) and *conversation theory* (Pask, 1975). The constructive learning model states that a learner has to act and reflect in an environment. Action could be a task of solving a problem and reflection could be abstracting from the derived solution and accumulating in one's experiential knowledge. The conversation theory suggests that learning to be successful requires continuous two-way conversations and interactions between the teacher/learner and amongst the learners. As discussed later, mobile learning has the capability of supporting both these learning theories.

2. Related work

The use of information and communication technology (ICT) has improved learning, especially when coupled with more learner-centered instruction (Zhu & Kaplan, 2002), or convenience, where learning and exchange with the instructor can take place asynchronously at the learner's own pace or on an as-needed basis (Palloff & Pratt, 2001). In addition, because wireless devices are highly *individualized* and *collaborative* communications tools they give faculty flexible tools for complementing the existing technologies and extending the learning beyond the classrooms and homes from remote places like airports or trains where students do not have access to computers and the Internet (Virvou & Alepis, 2005).

One reason why *m-learning* systems may not have been widely proliferated in education is due to a widening concern among faculty and administrators on the viability of the W/H devices in online programs. The introduction of W/H devices into the learning pedagogy raises concerns among faculty regarding their usefulness in education. For example, some faculty question whether students should be learning at the airport or a train station with all the environmental distractions? Nonetheless, several studies have been conducted to test the role of W/H devices for learning. They are reviewed here, briefly, for comparison with our project.

Farooq, Shafer, Rosson, and Caroll (2002) have extended an existing personal computer based online learning community, MOOsburg, to W/H devices to allow students participating in community education programs on environment and ecology to discuss their findings from remote field trips. As students collect and analyze environmental data they can either chat with their peers or interact with a database on the server. This application was developed with the Java software using thin-client architecture such that it can work on a variety of W/H devices within MOOsburg platform. Another similar m-learning project (Lehner & Nosekabel, 2002) extended an Internet-based virtual university to mobile devices by developing a m-learning platform called WELCOME (Wireless E-Learning and COMmunication Environment). This complements the e-learning environment by translating some of the contents for W/H devices and supplements it with new information such as event alerts, phonebook, calendar and other campus services. Both systems combine the browser-based pull technology with the WAP-based push technology to enrich the student's learning experience and support the conversational theory of learning.

Two other studies at European universities have focused exclusively on use of SMS technology as collaboration tools for m-learning. The first study (Bollen, Eimler, & Hoppe, 2004) emulated a W/H device on a PC to allow students send SMS messages on various discussion topics which were aggregated and categorized by the instructor, using an electronic whiteboard, in the

classroom. The categorization can be done by criteria such as sender, receiver, time, and others. The second study (Stone, Briggs, & Smith, 2002) evaluated the effectiveness of SMS campaign as a conversational mechanism in context of developing better quality mobile teaching and learning environment. The effectiveness SMS campaign was measured by quickness of the response, the quality of data collected, the impact of message complexity on number of responses and the method of campaign announcement on quality and quantity of messages. These studies demonstrated that students liked using SMS and they were responsive to the use of W/H devices for interaction and learning. The response rates were high and the quality of the messages was very good. SMS responses were also much quicker than email responses. Both these studies experiment with popular mobile messaging services to see whether they would work in m-learning environment and provide support for the conversational theory of learning.

Perhaps the most sophisticated m-learning tool is that of the Mobile Author (Virvou & Alepis, 2005) project which allows instructors to create an intelligent tutoring system (ITS) in any subject domain for their students. This system can be accessed either from a personal computer or a W/H device. The ITS can assess, record, and report student performance to the instructors. In addition, the system is customizable to student requirements and provides individualized advice to the students. Both instructors and students who evaluated this system found it to be very useful.

These examples demonstrate the value and show the potential of m-learning applications in education. Considering the popularity and support of W/H devices with the student population, it would be foolish to ignore them in any learning environment. Our study, discussed in the following section, builds on the knowledge and experience of these systems. We know from these studies is that the m-learning approach must complement an existing learning environment, developers must understand the limitations of mobile devices and use them for appropriate learning pedagogies like SMS and alerts to support the conversational model. When used properly, mobile technology can be popular with students and instructors. Therefore, our approach was to first understand the capability of mobile technology for learning and leverage it with successful learning models and approaches to develop a generic m-learning framework which can be adapted to varying m-learning requirements.

3. A mobile learning framework

Research on the introduction of ICT in education (Salomon, 1990; Welch & Brownell, 2000) has shown that it is effective only when developers understand the strengths and weaknesses of the technology and integrate technology into appropriate pedagogical practices. To address these concerns, an application framework is proposed for m-learning. This framework consists of two levels of research and analysis. First, is the *mobile connectivity* which focuses on the applications and technology used by commercial establishments to extend electronic commerce and second is the *e-learning*, which focuses on the use of Internet and other ICT in education.

3.1. Mobile connectivity

The immobile nature of PC and Internet has restricted the *anytime-anyplace* potential of e-learning to those moments when a learner is at home or at work in front of their PC (Steinfield,

2003). When in transit, a learner cannot access the courseware (course information and other applications) nor complete their course work. A wireless device overcomes these limitations by allowing learners to disseminate information and complete other course work even when they are away from their hard-wired Internet connections. This enhances the anyplace potential of wired Internet to the next level, namely, *anywhere* (Peters, 2002). A wireless device has the potential to give instant gratification to students by allowing them to interact with the instructors, other students in the course, and access course materials from wherever (or anywhere) they have wireless connectivity.

BenMoussa (2003) identifies several benefits for mobile connectivity. Mobile applications generally allow the user to control or filter the information flow and communication through the W/H device; namely, these devices are usually *personalized* or *individualized.* Second, mobile connectivity improves *collaboration* via real-time or instant interactivity, regardless of time and location, leading to better decision making. Finally, mobile connectivity enhances *customer orientation* as users have better access to their service providers and do a better job in balancing their work-life through a productive use of time. These benefits can prove equally useful for improving the learning environment.

Several commercial wireless service providers have started providing mobile data services. For instance, Verizon Wireless provides its subscribers with m-services which include local information, search engines, shopping, organizer functions and e-mail (Duggan, 2000). Similarly, AT&T/Cingular Wireless data services include SMS, content downloads, and ability to connect with personalized data like address books and calendars (Chidi, 2002). Zhang (2003) provides a mobile commerce framework for personalized and adaptive content delivery to tap into these commercial m-services. To counter the drawbacks of smaller display, lower speed, reliability and security of these services, the Zhang framework suggest the use of WAP gateway, agent profiler, caching proxies to deliver the content in a combination of *push* and *pull mechanisms* to the users. This not only reduces information overload, but also does a better job of delivering content according to the needs of user. The push model can be used for sending personalized multicasting messages, as discussed earlier, to a group of mobile users with a common profile thereby improving the effectiveness and usefulness of the content delivered. The mobile connectivity characteristics such as personalization and anywhere flexibility can be utilized in designing applications for mobile learning.

3.2. Electronic learning

Sharples (2000) contends that the advances in learning and technology have converged, since the early 1970s, setting the stage for a successful mobile learning environment. As learning has become more individualized, learner-centered, situated, collaborative, ubiquitous, and continuing, so has the technology; ICT has similarly become more personalized, user-centered, mobile, networked, ubiquitous, and durable. These parallel progresses offer the possibility for m-learning to support both the *social constructive theory* of learning and the *conversation theory* mentioned earlier. The Sharples (2000) framework provides five approaches for using technology in learning: (1) intelligent *tutoring systems* that have attempted to replace the teacher; these have never been successful due to their limited knowledge domains; (2) simulation and modeling tools that serve as *learner's assistants* or *pedagogical agents* embedded in applications that act as *mentors* providing

	Personalized Content	**Collaborative Content**	
PUSH Mechanism	*Pedagogical Agents & Mentors*	*Communication Aids*	*SMS, IM, Alerts, Scheduling Calendars*
PULL Mechanism	*System Tools & Resources*	*Simulated Classrooms*	*WML websites, Discussion Boards & Chat Forums*
	Alerts, Scheduling Calendars, WML websites	*SMS, IM, Discussion Boards & Chat Forums*	**M-learning Applications**

Fig. 1. A m-learning framework.

advice; (3) dictionaries, concept maps, learning organizers, planners and other resource aids that help learners to learn or organize knowledge with *system tools and resources*; (4) personalized *communication aids* that can present materials depending on user abilities and experience with the system; (5) *simulated classrooms* and labs that engage teachers and learners in an interaction similar to the real classrooms. The e-learning methods and approaches are also extremely useful for designing applications that incorporate the constructive learning and conversation theories into a mobile learning environment.

3.3. Framework

The framework, presented in Fig. 1, integrates the ideas from mobile connectivity and e-learning into application requirements for mobile learning. For example, the mobile connectivity research suggests the content delivery is more effective when a combination of push and pull mechanisms are used. Similarly, the content delivered is more useful when it is personalized (i.e., when students can control or filter the content) and collaborative (i.e., when students can reflect and react to the information that they receive), as suggested by the constructive and conversational learning models. The analysis of e-learning literature suggested a set of pedagogical approaches to support the constructive learning and conversation theories that have worked successfully in learning. The framework utilizes these pedagogical approaches to extend learning in a mobile environment.

Our framework supports the concepts outlined by other researchers (Bowman & Bowman, 1998; Gleason, 1995; Karayan & Crowe, 1997; Lowry, Koneman, Osman-Jouchoux, & Wilson, 1994; Palloff & Pratt, 2001) for e-learning environment, such as a provision of interactive forum for asking questions of the professor, a place to comment on information about the class or related topics, a delivery system for submitting or presenting assignments or class announcements, and development of a 24 × 7 learning community for the class.

4. Mobile learning application

An implementation of ICT into learning changes the pedagogical practices (Nachmias, Mioduser, Oren, & Ram, 2000). There is a lot of evidence to show it does not. The academic instruction

in online learning environment alters the traditional *time/space configuration* by providing access to learning resources from anywhere at anytime, *information and content delivery* is altered by presenting the materials in different media, parallel access paths, and assessments via computer logs and software packages. Similarly, *communication and interaction* process between the learner and teacher is altered with novel usage of synchronous and asynchronous communication tools that allow sharing of ideas, virtual collaboration and better archival capabilities for reflecting on previous interactions. Finally, ICT alters the roles of students and instructors. Students are empowered with the learning responsibility with their individual learning goals, schedules and assessments, while the instructor's role shifts from "a sage on the stage" to "a guide on a side" (Nachmian, 2002). One of the goals of this project was to explore whether these pedagogical shifts impact the m-learning environment as well.

Therefore, our prototype m-learning environment was evaluated with students from three courses during two different semesters. These courses already had websites. An internal university grant provided the funding to purchase a few popular mobile devices, applications, and a student research assistant to setup a m-learning environment accessible from W/H devices (or " *wapsite*"). This wapsite provides customizable RSS news alerts, discussion board, and chat room on W/H devices. The benefit of using the wireless access protocol (WAP) is that the site is accessible from a wide variety of W/H devices without modifications.

4.1. m-Learning architecture

The implementation consisted of customizing commercial mobile software used traditionally for business applications for the m-learning environment as per the requirements of our framework. The m-learning applications developed are available via any WAP-supported mobile device from a *wapsite* (comwebserver.uml.edu/forums/wiforums) and from a *website* (miscom.uml.edu/forums). Students are required to authenticate before accessing the materials. Screen-shots of the interactive forum and wapsite developed for courses are shown in Figs. 2 and 3, respectively.

A high level architecture of our mobile learning application is shown in Fig. 4. Students and class instructors can interact with course materials either from a personal computer or from a W/H device. Instructors have an administrative login for configuration and monitoring the contents while students have regular user login. The Macromedia Cold Fusion Server™ delivers the
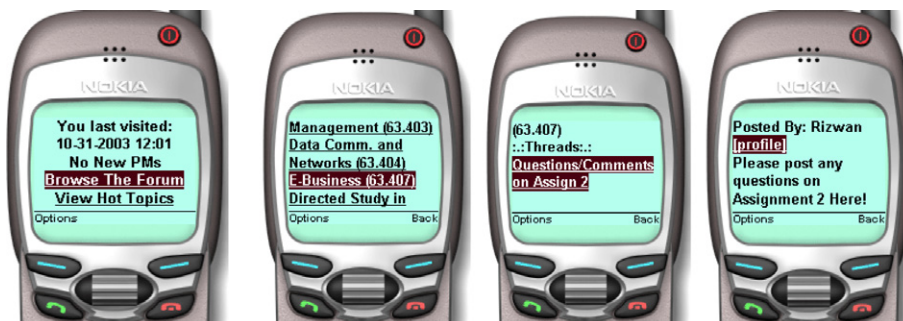

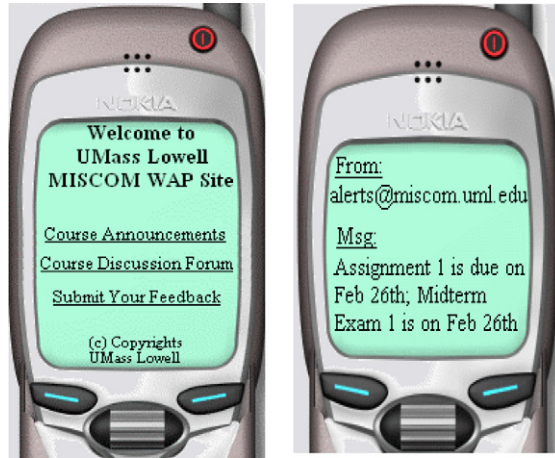Fig. 2. Interactive forum application.
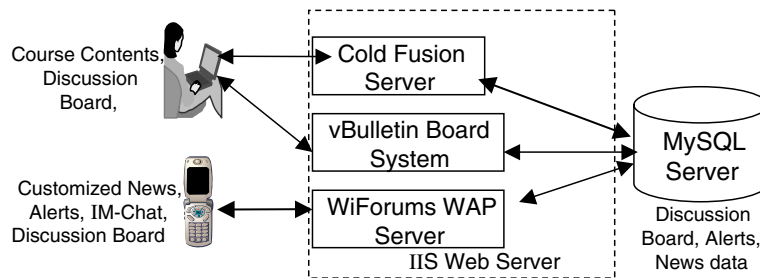
Fig. 3. WML wapsite.

Fig. 4. Mobile learning application architecture.

course contents through the Microsoft IIS™ web server to the personal computer (PC). The course interactions can be conducted both via PC as well as a W/H device. The vBulletin™ application provides access to the discussion forums via PC, while the WiForums™ application provides access via any WAP-enabled phone with Internet/data access service. The reason vBulletin and WiForums applications were selected is because they are open-source software and support thin-client architecture suitable for our WAP platform. They are platform independent, meaning it can work equally well on Windows or Unix-based operating systems and integrate with open-source database platforms like MySQL database server. The current version runs on Windows 2003 server on an Intel-Xeon processor.

A key benefit of this architecture is that it allows the course interactions and communications between users on PC with users on W/H device. Messages posted on PC can be instantly accessed on W/H device and students with W/H devices can exchange messages with students using PCs or notebooks. This is good for the m-learning environment as the critical mass (network effect) of W/H device users is not essential for this service to get started. Another benefit of this integration is that students can receive alerts when new messages are entered on the discussion board on their W/H device. The overall goal of this architecture was to value-add to the anytime/anyplace flexibility of e-learning.

4.2. Application evaluation

The two major goals for evaluating our application were to:

- observe the usage of this application in a classroom setting with students and obtain student feedback on our m-learning applications, and
- determine the student opinions on the role and value m-learning applications, in general, after participating in our study.

Therefore, the evaluation process was broken into two phases. In each phase students were shown how to access and use our application during a class session and were instructed to use the application for next few weeks of the semester. This was followed by two attitudinal surveys: in phase one the emphasis was only on student satisfaction with our application, while in phase two the emphasis was on student satisfaction and their general perceptions on the role of m-learning in higher education.

During the first phase of the evaluation, 19 undergraduate students from an on-campus senior year elective course were involved. Many of the students in this sample did not have a WAP-enabled phone or Internet data services to access our application. These students were instructed to download a wireless phone simulator software (see Fig. 5) called Wireless Companion™ to access the WAP user-interface on their PC.

The students task was to login to the course website from both website and wapsite to access the materials and interact with their peers and instructor. The system logged the usage of the students and also whether they accessed it from a website or wapsite. Students were informed about this and were specifically instructed that to get their participation grade for this assignment they were required to access the wapsite at least ten times. We felt the students should have some repetitive experience before making a judgment on our system. A review of the system log revealed that all the students in our sample had accessed the wapsite for ten or more times, during the testing period.

The students were given written instructions on how to access the wapsite through a handout which listed the steps on how to register/login, navigate and participate in the discussion board and chat.

An empirically validated survey instrument developed by Wang (2003) for measuring learner satisfaction for e-learning systems was customized for this study. Questions focusing on both usefulness of the m-learning system (MLS) as well as student satisfaction with the MLS were asked using a 5-point Likert scale with strongly agree as 5, neutral as 3 and strongly disagree as 1 on the Likert scale. The results from the first survey, after a two week testing period, are shown in Table 1 below.

The results from the first phase indicated that the students found our MLS useful (3.79) and a good complimentary tool for the classroom interaction (3.58). However, students in our sample were neutral on ease-of-use (2.68) but found the interaction tools easy for discussing course materials with other students (3.42) and instructors (3.32). The reason for this conflicting opinion on ease-of-use was later clarified by the students in a follow-up discussion. Most students in our sample found the mobile phone keypad and screens very difficult while navigating, reading and typing their messages. However, once they overcome this user-interface hurdle the m-learning

Fig. 5. Mobile phone simulator.

applications used for classroom interaction were easier to understand. Another possibility was that the students found the applications easy because they had used similar applications on the website before using them on the wapsite. Also, the mobile user-interface may not be a big issue with European or Asian students who are much more experienced with cell phones and SMS messaging (as shown in earlier studies).

The overall results from the first phase indicate that students were generally satisfied (3.16) with our MLS application and foresee MLS as a potentially useful tool for learning. However, because

Table 1
Results from survey of 19 students

MLS survey 1 ($N = 9$)	Average	Std. dev.
MLS was useful for the existing course	3.79	0.63
MLS was a good discussion tool	3.53	0.96
MLS was easy to use	2.68	0.94
MLS was easy to understand	3.00	1.05
MLS had a good forum for interaction	3.58	0.50
MLS was easy to discuss course material w/other students	3.42	0.90
MLS was easy to discuss course material w/the instructor	3.32	0.67
MLS was a convenient platform to access course discussions	3.79	0.85
Overall satisfaction with MLS	3.16	0.89
MLS has potential to become good learning tool	3.74	1.04
5 = strongly agree, 3 = neutral, 1 = strongly disagree		
Background questions	*Percent*	
Do you have a W/H device?	84.21%	
Can your W/H device access Internet?	43.75%	
Can you send SMS?	87.50%	
Willing to use wireless for e-learning?	57.89%	

of the small sample size and limited functionality of our application we cannot generalize the results for all MLS environments. Furthermore, because we used the WAP protocol for universal access, our application's user interface had limited visual appeal and navigational capabilities. This may have biased the student's perception on our system and our results. Therefore, we decided to modify the survey for our next study to capture the general perception of students on MLS as a tool for learning.

The second phase of the study was conducted with 44 students from two courses in the subsequent semester. The goal of this phase, as stated earlier, was to let the students experience our MLS environment but instead of just giving their feedback on our application, we wanted them to give us their perceptions on the potential role of MLS in learning. The students used this system for three weeks to access and discuss the class materials. This was followed by a survey using the same 5-point Likert scale used in the first phase. However, the survey questions were modified to emphasize not just on our implementation of m-learning system but on the use of mobile applications, in general, for e-learning. For example, this survey also asked the student's opinions through open ended questions like "What did you like most about using wireless devices for e-learning? What did you dislike most about using wireless devices for e-learning? What role do you foresee for wireless devices in e-learning? What functionality or features would make MLS a good learning tool?" The survey's objective was to get the students to think beyond the current implementation and focus on future implementations which will no doubt have better and easy-to-use interfaces. The results of the second survey are shown in Table 2 below.

The results from the second phase show that the students do foresee MLS as an effective learning tool or aid (4.22), providing flexible access from anywhere (4.27) and convenient to use application (4.05). Students also perceive an important supplementary role for W/H devices in e-learning (3.33) and are effective in delivering personalized content (3.7); the students preferred

Table 2
Results from 2nd survey of 44 students

| MLS survey 2 ($n = 44$)	Average	Std. dev.
MLS adds value to e-learning	3.75	0.92
MLS allows instant access regardless of your location.	4.27	0.66
MLS is useful to supplement to an existing course	3.64	1.04
MLS is an effective learning aid or assistant for students	4.20	0.70
MLS is an effective method of providing personalized information	3.70	0.85
MLS allows to convert any wait (dead) time into productive	3.89	0.95
MLS allows convenient access to discussions – anywhere and anytime	4.05	0.75
MLS that sends the information via messages may be better	3.50	1.00
MLS that also allows access to information from the website	3.80	0.98
MLS can be used as a supplemental tool for any existing course	3.33	1.19
5 = strongly agree, 3 = neutral, 1 = strongly disagree		
Background questions	*Percent*	
Do you have a W/H device?	86.36%	
Is your wireless device a Cell or Mobile Phone	79.55%	
Can your wireless device access data services?	63.64%	
Do you plan to have data services access from your wireless device?	59.09%	
Willing to use wireless for learning?	64.63%	
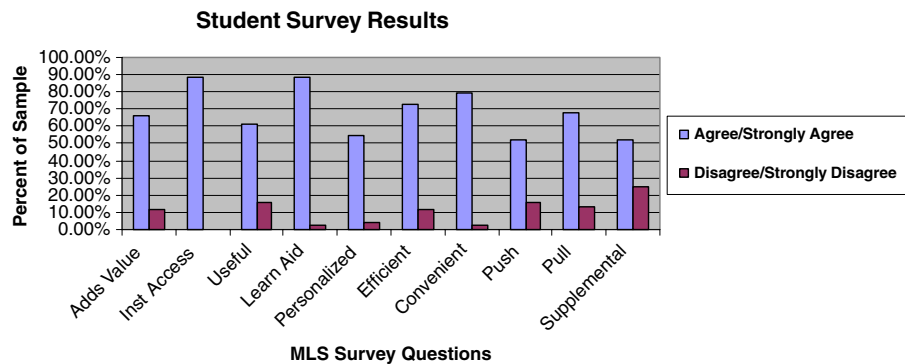
Fig. 6. Student survey agreement/disagreement analysis.

a combination of push (3.5) and pull (3.8) mechanisms for communication with the course website. Finally, the background data reveals that a large percent of the sample own a W/H device (86.9%) with a good majority (80%) owning cell phones. With the newer digital phones having low cost access to fixed-rate data services from 3G and Wi–Fi network services in the near future, the potential for more students having access to data service is bound to increase. This is welcoming news to educators because 65% of the sample was willing to use their W/H device for e-learning.

The survey results were also grouped by student agreement and disagreement on the ten questions (see Table 2) of our MLS survey. As shown in Fig. 6 there was strong agreement or agreement on all the ten questions. Students in general support the use of W/H devices in learning and foresee a strong role for these devices in improving flexibility and efficiency of the learning environment. For example, 89% of sample agrees that MLS gives instant access to course materials

from any location and effective learning aids or assistants. Similarly, over 60% agree that MLS adds value to learning and is a useful learning tool. The qualitative comments from the students support the quantitative results. Students liked the convenience, ease-of-use, ability to be reminded, and the mobility factor which allowed them to utilize any dead-time for productive learning activity. But they also disliked the small screen-size, tedious process of typing on phone keypads, and slow connection speeds, response times, lack of pictures and visual stimulation. The following comment from a student pretty much summarizes the role of m-learning:

> *"Being a student who is constantly on the go, and working 25+ hours a week while being a full time student, I see wireless devices being used for personal alerts and reminders for course due dates, grade standing, and such. I think they would work great given 2 things: They will be a part of bigger http website offering. They are used for pull media more than interactive."*

In sum, the evaluation study was successful because it gave us some feedback on what the students think about our MLS, helped us determine whether the students find the flexibility of W/H devices useful for learning and their opinion on the role of a m-learning in education. It should be pointed out that the small sample size of this study limits generalization (or external validity) of the results; nonetheless, it does give a first glimpse on understanding the role of m-learning applications in higher education with US students. This feedback helps us move forward to the next phase of this research project, namely, evaluating the student learning outcomes with the use of mobile technology. While the current generation of W/H devices and wireless network services limits their ability usefulness for e-learning, they are useful tools to supplement existing e-learning environments (3.64). Our study confirms the findings of previous research discussed earlier. W/H device usage is bound to increase in the future and they will have a significant impact on the quality of student learning.

5. Conclusion and future directions

This paper has discussed and demonstrated how learning can be extended to W/H devices with a mobile learning framework and developed a prototype application from of the requirements generated from the framework. This application was evaluated with students from both online and on-campus classroom environments to explore m-learning feasibility and get valuable feedback from the potential users. Our experience with this project demonstrates that most learning pedagogies from constructive learning and conversation theories can be adapted for a mobile learning environment. The key is to understand the strengths and weakness of a particular technology, while deploying good pedagogical practices to achieve specific learning goals. Beyond looking at system decisions, a look back at learning pedagogies helps the overall m-learning strategy. The following quote from Ellis (2003) is appropriate for all researchers integrating new technology in education:

> *"It is a different learning environment, but there are some of the same painful learning lessons that people are learning early on. You can't take PowerPoint to the Web and call it e-learning. You need good instructional design, you need flow, and you need to build learning objects. And all of the [pedagogical] things that make e-learning on a big screen PC or laptops effective still exist with the consideration of a mobile application."*

Table 3
A comparison of e-learning with m-learning

Pedagogy	e-Learning class	m-Learning class
Course location	HTML website	WML website
Class materials	Online notes, URLs and presentation slides	URL links to course website
Class experience	Whiteboards, group touring, virtual demos, chat rooms, discussion boards, and e-mail	SMS, alerts, discussion boards, course calendar
Assignments/projects	E-mail attachment or posting with web forms	Instant messaging for project coordination
Student assessment	On-line exams, chat room/ discussion board participation	On-line exams, chat room/ discussion board participation

Also, the granularity of the content delivered is critical. It is not possible for someone to take a two-hour course on a W/H device. The power of m-learning technology can be leveraged by complimenting the existing courses with value-added features such as alerts, personalized agents or communications aids, and access to interaction or discussion utilities that help users convert their dead-time to productive activity while in transit without an access to computers and Internet. Table 3 summarizes the differences between a classroom using mobile devices (or m-learning) with a classroom using computers (or e-learning) to supplement their learning activities. The differences are in the tools but the pedagogies remain similar. m-Learning does extend the flexibility of learning from anytime/anyplace to anywhere.

This flexibility may result in some consequences that learners may not have imagined. One short-term drawback of extensive use of mobile technologies by learners is the problem of information and interaction overload. Anytime and anywhere connectivity may become 24×7 headaches; which may result in the danger of learners becoming chaotic. On the other hand, access to information at the point of relevance may make it possible for adult learner to minimize their unproductive time, which may enhance their work-life-education balance. Although mobile devices will always be small, new technology is being developed to allow these devices to project an infrared (virtual) keyboard on a user's desk and a large screen image on the wall for a better visual display.

Although it seems inevitable that m-learning will soon be an essential extension of e-learning, this transition will not occur over night. The promise of instant access to learning anytime and anywhere is an enormous benefit, but will be restricted until the technology of wireless data access matures and educators learn how to apply appropriate pedagogies from both social constructive and conversational theories, mentioned earlier. A major bottleneck from the student's point of view for our current application was the user-interface. Therefore, in the next phase, we plan to explore how to enhance user-interfaces with speech recognition technology. For example, interactive voice recognition (IVR) technology can be used for voice-activated user navigation and voice messages can be converted to text before sending them on the discussion board. These enhancements are crucial for sustaining the growth of mobile devices in education.

References

BenMoussa, C. (2003). Workers on the move: new opportunities through mobile commerce. Presented at *the Stockholm Mobility Roundtable*, May, 22–23.

Bollen, L., Eimler, H., & Hoppe, U. (1999). SMS-based discussions – technology enhanced collaboration for a literature course. In *2nd IEEE international workshop on wireless and mobile technologies in education (WMTE'04)* (pp. 21–22).

Bowman, R. L., & Bowman, V. E. (1998). Life on the electronic frontier: the application of technology to group work. *Journal for Specialists in Group Work, 23*, 428–445.

Brown, A., & Campione, J. (1996). Psychological theory and design of innovative learning environments: on procedures, principles, and systems. In L. Schauble & R. Glaser (Eds.), *Innovations in learning: new environments for education* (pp. 289–325). Mahwah, NJ: Erlbaum.

Chidi, G. A. (2002). AT&T wireless launches mobile web service in US. *Wireless IT World*. Available from http://wireless.itworld.com/4256/020416attwireless/page_1.html (accessed Dec, 2004).

Duggan, E. (2000). Verizon hits the horizon at full speed. *The Business Journal*. Available from http://southflorida.bizjournals.com/southflorida/stories/2000/08/28/story8.html (accessed Aug, 2004).

Ellis, K. (2003). Moving into m-learning. *Training, 40*(10), 12–15.

Farooq, U., Shafer, W., Rosson, M. B., & Caroll, J. M. (2002). M-education: bridging the gap of mobile and desktop computing. In *IEEE international workshop on wireless and mobile technologies in education (WMTE'02)* (pp. 91–94).

Gleason, N. A. (1995). A new approach to disordered eating: using an electronic bulletin board to confront social pressure on body image. *Journal of American College Health, 44*, 78–80.

Green, K. C. (1999). The 1999 National Survey of Information Technology in US Higher Education – The Continuing Challenge of Instructional Integration and User Support. *The Campus Computing Project*, Center for Educational Studies, The Claremont Graduate University, Claremont, CA 91711.

Green, K. C. (2000). Technology and instruction: compelling, competing, and complementary visions for the instructional role of technology in higher education. Available from http://www.campuscomputing.net (accessed Nov, 2004).

Homan, S., & Wood, K. (2003). Taming the mega-lecture: wireless quizzing. *Syllabus Magazine*, Oct 7–8.

Jones, S. (2002). The Internet goes to college: how students are living in the future with today's technology. *Pew Internet and American Life Project*, Sept. (accessed Oct, 2004). Available from http://www.pewinternet.org.

Karayan, S. S., & Crowe, J. A. (1997). Student perspectives of electronic discussion groups. *T.H.E. Journal, 24*, 69–71.

Lehner, F., & Nosekabel, H. (2002). The role of mobile devices in e-learning – first experiences with a wireless e-learning environment. In *IEEE international workshop on wireless and mobile technologies in education (WMTE'02)* (pp. 103–106).

Lowry, M., Koneman, P., Osman-Jouchoux, R., & Wilson, B. (1994). Electronic discussion groups: using e-mail as an instructional strategy. *Tech Trends, 39*, 22–24.

Nachmian, R. (2002). A research framework for the study of a campus-wide web-based academic instruction project. *Computers and Education, 5*, 213–229.

Nachmias, R., Mioduser, D., Oren, A., & Ram, J. (2000). Web-supported emergent collaboration in higher education courses. *Educational Technology and Society, 3*(3), 94–104.

Palloff, R., & Pratt, K. (2001). *Lessons from the cyberspace classroom: the realities of online teaching*. San Francisco, CA: Jossey-Bass.

Pask, G. (1975). Minds and media in education and entertainment: some theoretical comments illustrated by the design and operation of a system for exteriorizing and manipulating individual theses. In R. Trappl & G. Pask (Eds.). *Progress in cybernetics and systems research* (Vol. 4, pp. 38–50). Washington and London: Hemisphere.

Peters, B. (2002). The future of wireless marketing. *Wireless Advertising Association*. Available from http://www.wmrc.com/businessbriefing/pdf/wireless2002/publication/peters.pdf (accessed Oct, 2004).

Quinn, C. (2001). Get ready for m-learning. *Training and Development, 20*(2), 20–21.

Salomon, G. (1990). Studying the .ute and the orchestra: controlled vs. classroom research on computers. *International Journal of Educational Research, 14*, 521–532.

Setaro, J. (2001). If you build it, will they come? Distance learning through wireless devices. *Unisys World*(July), 12–14.

Sharples, M. (2000). The design of personal mobile technologies for lifelong learning. *Computers and Education, 34*, 177–193.

Steinfield, C. (2003). The development of location based services in mobile commerce. Michigan State University Report. Available from http://www.msu.edu/~steinfie/elifelbschap.pdf (accessed Sep, 2004).

Stone, A., Briggs, J., & Smith, C. (2002). SMS and interactivity – some results from the field, and its implications on effective uses of mobile technologies in education. In *IEEE international workshop on wireless and mobile technologies in education (WMTE'02)* (pp. 104–108).

Virvou, M., & Alepis, E. (2005). Mobile educational features in authoring tools for personalized tutoring. *Computers and Education, 44*, 53–68.

Wang, Y. (2003). Assessment of learner satisfaction with asynchronous electronic learning systems. *Information and Management, 41*, 75–86.

Welch, M., & Brownell, K. (2000). The development and evaluation of a multimedia course on educational collaboration. *Journal of Educational Multimedia and Hypermedia, 9*, 169–194.

Zhang, D. (2003). Delivery of personalized and adaptive content to mobile devices: a framework and enabling technology. *Communications of the Association for Information Systems, 12*, 183–202.

Zhu & Kaplan (2002). Technology and Teaching. In W. J. McKeachie (Ed.), *McKeachie's teaching tips: strategies, research, and theory for college and university teachers* (pp. 204–224). Boston: Houghton Mifflin Company.