Design and Development of a Device-Independent System for Mobile Learning

Razieh Niazi and Qusay H. Mahmoud, *Senior Member, IEEE*

***Abstract*—With the high penetration rate of mobile phones among people especially the young, and the advancement in mobile technologies and wireless networks, educators are optimistic about the potentials of mobile phones in education. Several research studies have been published about the pedagogical effects of mobile learning in higher education. However, little attention has been given to the design and development of mobile learning systems. There is a need for innovative, reliable and usable software for mobile learning. The work presented here is focused on the design and development of new applications and systems for both educators and learners to enable mobile learning. In this paper, we present a mobile learning system which supports both educators and learners. Using this system, instructors are able to generate quizzes for various target devices. In addition, it offers learners seamless on-line as well as off-line access to the quizzes from any device.**

***Index Terms*— Mobile Learning, M-Learning Java ME, Blackberry Devices, Quiz Generator, Device-Independent**

I. Introduction

IT is estimated that by 2008 there will be 3 billion mobile subscribers worldwide [1], whereas the number of PC users is expected to reach 1 billion by 2010 [2]. People are comfortable with their cellular phones because they are inherently personal, mobile, small in size and lightweight. They support different capabilities and services such as voice, SMS for text messaging, email, Internet, MMS for sending and receiving photos, and camera for taking pictures. Also, some mobile phones act as mp3 players and mass storage of music, photos, images, and documents. In other words, mobile phones have progressed as a device for communication and entertainment. However, they still have lots of potentials for new additional revolutionary applications and usages. For example, in Japan, mobile phone companies provide instant emergency earthquake alerts to their customers [3, 4]. In Sri Lanka, GSM cell phone signals were used to track tsunami survivors and to identify victims. In Ireland, Catholics now sign up for daily inspirational text messages from the Pope on their cell phones, and Muslims around the world can use their cell phones to find the direction of Mecca using a built-in compass [5]. In pervasive healthcare, it is expected that people would wear biological sensors which gather vital data, transmit them to their mobile phones for further processing, and in the case of life threatening situations the phone generates an alarm and/or calls an emergency center. All of these changes and evolutions show that we are in the Mobile Age – the age of mobile technology and mobile communication. Hence, there is little surprise that there is a growing interest in utilizing mobile technology into a variety of fields including learning.

Mobile learning (or m-learning) is the combination of e-learning and mobile computing that promises the access to applications which support learning at anytime and anywhere [6]. It goes beyond the e-learning experience and makes learning even more available and accessible. In other words, it makes learning experience available at anytime and anywhere, just for the right person and just on the right device [14]. It does not matter whether you are in a college, workplace, museum, coffee shop, or on the go.

Mobile learning can be employed to establish pervasive learning environments to make learning experience pervasive. In pervasive learning, education will be available for people at all levels, from toddlers to seniors, even people who are hard-to-reach, people in rural areas with limited learning resources or people who have been geographically isolated.
Mobile learning utilizes handheld devices such as smart phones, PDAs and other similar mobile phones in learning, although there are some debates on the inclusion of tablet PCs and laptops [7]. However, in mobile learning, given the wide variety of mobile devices available, hardware is considered a solved problem; the challenge is now in developing innovative, usable and affordable software applications and services for these devices [6]. Hence, we have focused on the design and development of new applications and tools for both educators and learners to enhance mobile learning. In this paper, we present our proposed system to generate quizzes, which is part of a larger framework for mobile learning. Our system is called MLQ (Mobile Learning Quiz). MLQ allows educators to create quizzes once and then generate the same content automatically

R. Niazi is a PhD student in the Department of Computing and Information Science, University of Guelph, Guelph, ON, N1G 2W1 Canada (rniazi@uoguelph.ca).

Q. H. Mahmoud is an Associate Professor in the Department of Computing and Information Science, University of Guelph, Guelph, ON, N1G 2W1 Canada (qmahmoud@uoguelph.ca).

Publisher Identification number 1558-7908 -062008-03

for various target devices including cellular phones, smart phones, PDAs, tablet PCs, laptops and PCs. In this system learners are able to manage their courses, take quizzes, view their marks, and receive messages and notifications from any target device. We have designed and developed two Learning Management Systems (LMSs): one for mobile users (mobiLMS) and the other for PC users (eLMS).

The rest of the paper is organized as follows. In Section 2, we discuss motivations in mobile learning and designing our system. We summarize the current related works in Section 3. The proposed approach and architecture are presented in Section 4. In Section 5, we discuss our implementation. Finally, Section 6 presents the conclusion and future work.

II. MOTIVATION

To illustrate the motivation for the proposed system, consider the scenario where a student waiting for a bus or sitting in a coffee shop, or even traveling. S/he can easily review course lecture, download an assignment or take a quiz using her/his mobile phone. Today, we are faced with "information overload", which means that, information is produced faster than we can process them. Hence, using our time wisely is one of the most important things which we should pay attention to it. We believe that utilizing mobile phones for learning will be a great idea. This can be considered from two aspects: first, they are small, cheep, portable, very handy, lightweight and can always be carried by people, and secondly, they are pervasive. So far, there is a high rate of mobile phone ownership and still growing. The other important key is the personal nature of mobile phones which are used as a device for entertainment, communication and building relationships with friends. According to the Wireless Kids project [8], in the UK, most teenagers considered the mobile phone as being an important part in their lives. Due to the above, many educators are optimistic about potential of using mobile phones in learning but as we have mentioned earlier, there is a need for innovative applications and services to enable mobile learning.

Although utilizing mobile phones for learning would be a great step towards the higher education and enhanced learning, there are some difficulties in implementing software for these devices. Some issues are due to the limited resources in cell phones such as its small screen size. The question is how to fit the learning materials onto the small screens without any impact on learning performance? The other issue is the fact that there is a wide variety of mobile phones. Today, there are various mobile phones with different capabilities in screen dimension, resolution, processing power, memory usage and so on. Thus, once we develop an application for a particular device, it may not be rendered on other devices. Quinn states that an m-learning solution must work for a broad range of devices, not only for a set of devices [9]. We adopt this specification. Thus, m-learning applications should be capable of device-independent delivery of content materials. The other issue can be reusability of content materials for both PC and mobile platforms. It is time-consuming, and even impossible, for educators to create materials for all targeted platforms separately. We address these issues in our proposed system.

III. RELATED WORK

Several research projects have proposed using mobile phones for taking quizzes while on the go. A large number of tools have been created and marketed to mobile users (although many of them have been in the gaming domain). However, there is still no standard specification for mobile learning systems including mobile quizzes. Therefore, we categorized the related work as follows and in each category we describe briefly the differences between our system and the other system:

A. Game Programs

Game programs such as Tribal/CTAD [10]. Tribal/CTAD is a game program which allows teachers to create snap quizzes, multiple–choice quizzes, and others. It is able to check the answers and track learners. However, it outputs Flash (swf) files which are suitable for Pocket PCs. It does not support other devices that do not have a flash runtime system.

B. SMS Authoring Tools

SMS authoring tool [11] allows authors/ teachers to setup an automated response system for a multiple choice quiz. Using this tool, authors present their questions in a variety of ways using a poster, a paper handout, or a web site. Participants use SMS text messaging to answer the multiple choice questions.

C. WAP Applications

A large number of mobile quiz applications use technologies such as WAP (Wireless Application Protocol) [13]. These kinds of systems only support browser-based technologies. In addition, they do not support off-line learning.

D. Others

In [12], an adaptive mobile learning system proposes an architecture and prototype quiz system based on XML/XSLT technologies. This system works on both PCs and mobile devices. However, it is a dynamic quiz system which does not support off-line learning.

IV. PROPOSED SYSTEM

The objective of this work is to design and develop an m-learning system that supports both learners and instructors on a wide variety of devices. Using this system, educators are able to generate quizzes for both PC and mobile device platforms. This system supports a variety of devices, including cellular phones, smart phones, PDAs, laptops, Tablet PCs and PCs. Also, it supports e-learning. The proposed system has the following characteristics:

Creating Quizzes

We believe that creating educational materials including quizzes should be done just once by the instructor, and then

have the same content generated for various target devices in a transparent manner just by clicking a button.

Delivering Quizzes

Our system supports both offline and online learning. It is able to deliver educational materials online as well as offline. In the case of online learning, delivery of quizzes to mobile devices is done in XML format which is a standard and universal data format. On the other hand, for offline learning there are some challenges, including the variety of mobile phones that our system addresses. Students have different brands of mobile phones with different capabilities and constraints. Our system provides device-independent delivery.

In both cases of offline and online learning, it is necessary to minimize the use of bandwidth and memory that consequently leads to less power consumption. Hence, in designing and developing our system, we have considered these three factors to keep them at a minimum.

Tracking and Evaluating Student's Progress

This part provides some facilities to give feedback to student's work such as displaying correct answers when a student submits his/her quiz, reviewing answers, grading the quiz, and sending the results back to the instructor. Also, students are able to try a quiz "N" times depending on the trial number defined by an instructor. Hence, the system is highly customizable.

Learning Management System (LMS)

LMS is a Web-based learning management system which allows all educators to access, assemble, package and redistribute course materials and quizzes. It also enables students to manage their courses, access the content and educational materials generated by instructors.

In addition, a mobile version of LMS (mobiLMS) available for online learning is supported in our system. This mobiLMS which is developed to be deployed on mobile phones enables learners to connect to our server and uses educational materials online.

Making Educational Materials Knowledge –Based

It offers instructors the opportunity to share their quizzes with other instructors. When instructors create their learning materials like quizzes, they have a chance to make their quizzes knowledge-based. If they take this opportunity, their quizzes will be saved in a knowledge-based database (KB database). This capability gives other instructors the chance to create their quizzes from this knowledge-based database randomly with respect to their keywords and topics searched, although they still have a chance to provide their quizzes from scratch.

Supporting Learning Metadata

All quizzes are saved in XML format. The system also has the capability to keep track of courses, content materials, labs, assignments, quizzes and their relationships for each instructor as metadata in the XML format.

Content Distribution Capability

This capability offers instructors the ability to create their educational materials like lectures, labs, quizzes once, then generate and distribute them in different formats including XML, HTML, XHTML, WML, JAVA ME Midlet for Java-enabled devices and Blackberry API code for Blackberry devices.

A. *System Architecture*

We have partitioned the system architecture into two levels (Mobile and electronic Learning Management Systems) and 4 different layers (storage layer, management layer, logic layer and presentation layer). We have two Learning Management Systems (LMS) because our system supports e-learning (PC platform) as well as m-learning (mobile phones). Figure 1 depicts the architecture of the proposed system.

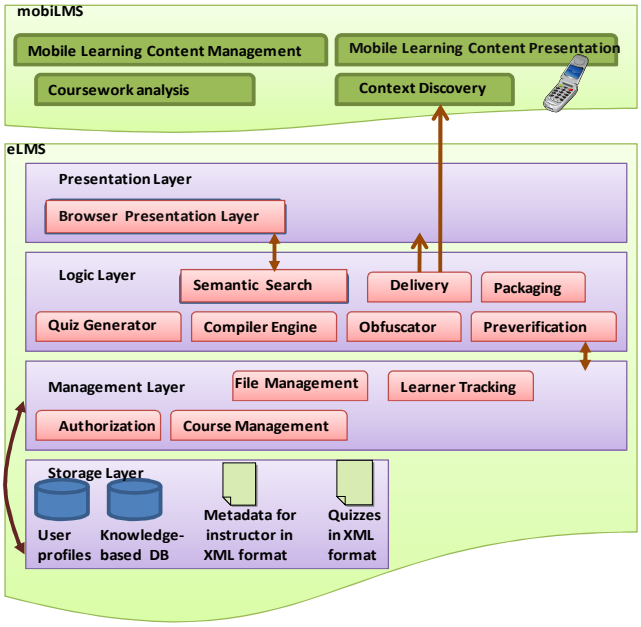

Fig. 1. The architecture of the proposed system.

MobiLMS is a platform to support mobile learning. Its responsibility is to manage courses, discover quizzes for each course, display scores, send messages and notifications, grade quizzes, and display quizzes on a variety of mobile devices. Technically, we summarize the mobiLMS into the following units:

- Mobile Learning Content Management to manage courses.
- Mobile Learning Content Presentation to present educational materials adaptive to mobile devices.
- Context Discovery to discover the context including the available courses and quizzes.
- Coursework Analysis to analyze coursework, assign grades, display correct answers and send results to instructors.

eLMS is a web-based Learning Management System categorized into the 4 following layers:

Presentation Layer

This layer is responsible for converting generated quizzes to the web browser in and adaptive form. In this layer, we use stylesheet, XSL, to convert quizzes in the XML format (generated in the logic layer) to the HTML.

Logic Layer

This layer mostly provides and performs functions to generate, compile, pre-verify, pack and deliver the educational materials in different formats including XML, WML, XHTML, JAVA ME Midlet and Blackberry API code. Technically, the functions of this layer are available to instructors. In the following we provide a brief description of each function:

- Generator has the responsibility for converting quiz instructor-specified inputs into the WML, XHTML, XML, JAVA ME Midlet, and Blackberry API compatible source code.
- Compiler Engine has the responsibility for compiling Java source codes to Java bytecodes class files. Our architecture supports two compilers: JAVA ME compiler and Blackberry API compiler.
- Obfuscator improves the size, performance and security of JAVA ME mobile applications.
- Preverification is applied on JAVA ME CLDC application bytecodes. In order to enable JAVA ME bytecodes class files to be run on mobile phone devices, they should be valid bytecodes. Preverification function converts JAVA ME bytecodes to valid bytecodes.
- Packing function is used to pack bytecodes. In order the generated codes be able to run on mobile phone devices, it is necessary to pack bytecodes and the relevant information to a special format such as jar or cod files.
- Delivery function is responsible for delivering quizzes in different formats to mobile devices.
- Semantic Search is a tool to query the Knowledge-Based quiz database. It is responsible for searching and finding the relevant quizzes which are matched with the entered user's keywords.

Management Layer

This layer is responsible for managing courses, users, and files. This layer provides and performs functions available to both educators and learners. The following is a brief description of the functionality of each component at this layer:

- Authorization is used to authenticate and authorize users.
- Course Management is used to manage courses for both instructors and learners. It enables students and teachers to add, delete and edit courses.
- File Management provides facility to manage the copy and removal of the generated files into the user's directories and the relevant subdirectories.
- Learner Tracking enables instructors to keep track of students' progress by receiving students' coursework feedback and quiz result through email or SMS.

Storage Layer

The system includes tables for user profiles, students, instructors, courses and other relevant information. In addition, it includes tables for knowledge-based quizzes. There are other repository formats other than tables like XML files and metadata as well. Metadata are used to keep track of instructor's activity. Here is a brief description of each component:

- Knowledge-based database used for managing quizzes as described earlier.
- User Profiles hold information about learners' profiles, instructors' profiles, courses, instructors' courses, and students' courses.
- Metadata which is in an XML data format keeps track of quizzes courses and their relationships for each instructor.

B. *Development Principals*

There are also some important criteria or principles that we have considered during the development of our system. These principles can be summarized as follows:

Cost Issues

We consider cost as a high propriety criterion while we are developing mobile applications. Because we believe that if a system wants to be applicable especially in our scopes which mostly are students, it should be cost effective. That's why our platform generates both off-line and on-line materials. In fact, in order to reduce the cost of communication, learners can use on-line materials while they are on campus and off-line materials while they are off-campus. Using off-line materials can also avoid inconvenience of signal disruption. In addition, in our implementation, we have kept the size of midlets and generated educational materials to a minimum. This can save bandwidth and reduce the cost of communication when learners are using the on-line materials. Also, it saves on memory usage.

Data Availability

It determines whether generated educational materials are always available for learners either on-campus or off-campus. In order to support this criterion, our platform generates both off-line and on-line quizzes. Hence, learners can always have access to quizzes. It does not matter whether they are on-campus or off-campus.

Ease of Use

The system is friendly and easy to use for both learners and teachers. Indeed, teachers put minimum efforts to generate the same materials on a variety of devices.

V. IMPLEMENTATION

Our system consists of 3-tiers including mobile phone devices and PCs as the client tier categorized into educators and learners, servlets that support LMS functions as the logic tier, and the database as well as metadata and XML file as the data tier.

Starting with the client tier, we have two kinds of client groups, instructors and learners.

A. *Instructors*

In order to illustrate how our system works, we follow an instructor named Bob who uses MLQ to generate his quizzes. First of all, he logs in to the system and chooses the course for which he wants to design a quiz. If the course does not exist, he can add it to his profile. Bob has three options to generate a quiz: generating a quiz from scratch, generating a quiz from the repository (knowledge-based quiz database), and generating a quiz from an existing quiz XML file (i.e. update an existing quiz):

Generating a Quiz from Scratch

In order to generate a quiz from scratch, Bob customize the quiz generator interface. Figure 2 shows these configurations:

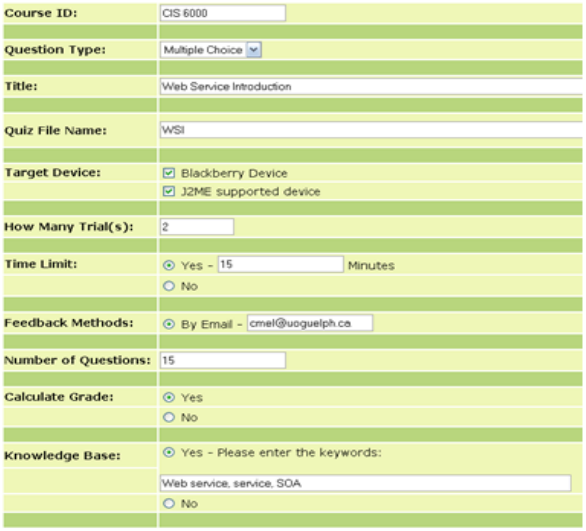

Fig. 2. Setup the quiz configuration.

Then, he enters the quiz questions and their answers, and selects the correct answer for each question as shown in Fig. 3.

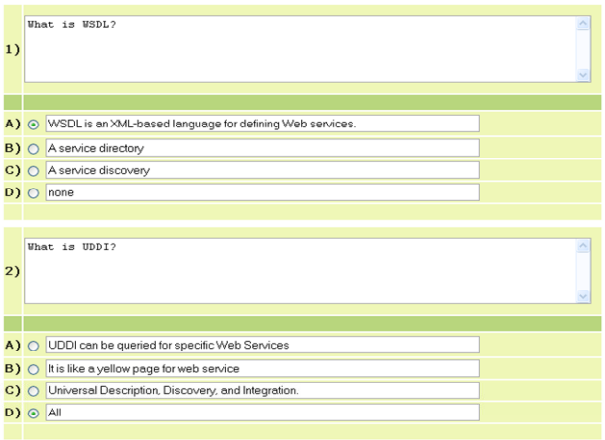

Fig. 3. Sample quiz questions.

In the final step, he clicks on a button to generate the quiz in various formats for different target devices as shown in Fig. 4.

Target	Description	Action
XML	Please download XML file, then you can always have your quiz and you will be able to update or change the quize just by click on the "Update Quiz" link at the toolbar.	Download XML
CLDC-1.x MIDP-2.0	CLDC-1.x, MIDP-2.0. Please download jar and jad file. In order to upload the code into the mobile device , Please read the instruction file.	Java ME Devices-JAD Java ME Devices-JAR Download Instruction
CLDC-1.0 MIDP-1.0	CLDC-1.0, MIDP-1.0. Please download jar and jad file. In order to upload the code into the mobile device , Please read the instruction file:	Java ME Devices-JAD Java ME Devices-JAR Download Instruction
BlackBerry	Please download the code file. In order to upload the code into the mobile device , Please read the instruction file:	BlackBerry Devices
WAP 1.x	WAP 1.x . Please download WML pages in order to enable students to have online quiz.	WML file WMLScript
Desktop Browser-based Client	You can also generate Desktop Browser Client (HTML/XHTML) simply by clicking the following link.	Generate Browser Desktop Client

Fig. 4. The quiz generated for various targets.

Generating a Quiz from the Knowledge-Based Quiz Database

Instructors can generate quizzes randomly from the KB database. For this purpose, first they enter the quiz topics which they are looking for and the number of questions. The system will provide them with a list of quizzes. Instructors can select the desired questions from each quiz and then click on a button to generate the quiz for various target devices as shown in Figure 4.

Generating a Quiz from an Existing Quiz XML File (Update Quiz)

Instructors are able to change their quiz and update it. For this purpose, first of all they should upload the quiz XML file. Then, they are able to change the quiz's configurations as well as the questions and answers. Finally, they can re-generate the quiz again with a click of a button. The quiz will be generated again for all selected target devices and the updated date and time will be added to the quiz XML file.

B. *Learners*

Clients are categorized into 3 groups including instructors who use an e-learning platform to take advantage of teaching tools and manage courses and students, learners who use an e-learning platform and learners who use an m-learning platform. We now discuss the system from the learner's viewpoint. There are two platforms for learners. One is e-learning platform which provides web-based tool for them to access their course materials and the relevant quizzes, view their grades and the instructor's feedbacks, messages and notifications. For the m-learning platform, there are two types of materials, off-line as well as on-line materials:

Offline Quizzes

Learners are able to download off-line quizzes onto their mobile phones in different ways including infra-red, USB, and Bluetooth. Using off-line quizzes is very cost effective because they do not have to use bandwidth to download the quiz materials onto their mobile phones. As we mentioned earlier, student have different mobile phones from different vendors, but our system supports a variety of target devices as follows:

TABLE I
OFF-LINE QUIZ FORMATS

Runtime System	Device
CLDC 1.x, MIDP 2.0	Java-enabled device
CLDC 1.0, MIDP 1.0	Java-enabled device
Blackberry OS	Blackberry device

Figure 5 shows some screen shots of an off-line quiz in the Blackberry 8800 device simulator.

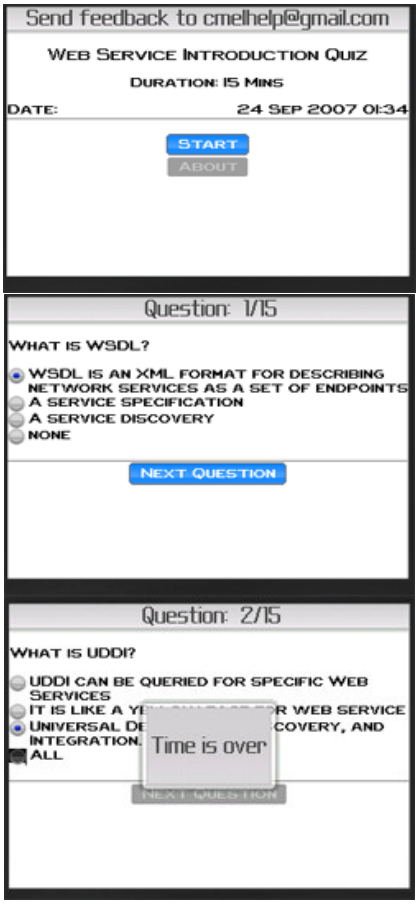

Fig 5. An offline quiz on the Blackberry 8800 device simulator.

Online Quizzes

In this format, we use two different technologies: browser-based and native. In browser-based technology, we support WAP 1.x and WAP 2.x protocols.

In native technology, mobiLMS communicates with the eLMS over open standards such HTTP and XML. In the native format, a customized application is deployed on the device to communicate with the server.

VI. CONCLUSION AND FUTURE WORK

In this paper we have discussed the design and development of a device-independent system for mobile learning. The quiz generator is part of a larger platform for mobile learning. We discussed the system architecture of the proposed system and the proof of concept implementation we have built using Java technologies. We presented how the proposed system addresses the issues in mobile learning including reusability of content, support for a variety of mobile devices, and device-independent delivery of content.

Currently, we are working on the design and development of tools for generating course materials, such as lecture slides and notes that can be adapted to various mobile devices. Similar to the quizzes, the course materials would be created once and with a click of a button and generated for various target devices.

REFERENCES

[1] Reardon, M. (2007). Emerging markets fuel cell phone growth, http://www.news.com/2100-1039_3-6159491.html (accessed September 23, 2007).

[2] Kanellos, M. (2004). A billion PC users on the way, http://www.news.com/A+billion+PC+users+on+the+way/2100-1003_3-5290988.html (accessed September 23, 2007).

[3] Mobile Phone Culture or Customs. (2006). http://apsidalkat.blogspot.com/ (accessed September 23, 2007).

[4] NTT DoCoMo and KDDI Develop Platform for Immediate Notification of Emergency Earthquake Alerts. (2007). http://www.kddi.com/english/corporate/news_release/2007/0530/index.html (accessed September 20, 2007).

[5] Wagner, E. D. (2005). Enabling mobile learning. EDUCAUSE Review, 40(3), pp. 40–53.

[6] Holzinger, A., Nischelwitzer, A., Meisenberger, M. (2005). Lifelong-Learning Support by M-learning: Example Scenarios. ACM eLearn Magazine, 2005(11).

[7] M-Learning India. (2007). Introduction to Mobile Learning http://www.mlearningindia.com/index.php?option=com_content&task=view&id=12&Itemid=1.

[8] Oksman, V. (2006). Young People and Seniors in Finnish 'Mobile Information Society'. Journal of Interactive Media in Education,http://www-jime.open.ac.uk/2006/02/oksman-2006-02-04.html (accessed July 9, 2007).

[9] Quinn, C. (2000). Mobile Learning: Mobiles, Wireless, In-Your-Pocket Learning. LiNE Zine, http://www.linezine.com/2.1/features/cqmmwiyp.htm (accessed June 15, 2007).

[10] SMS quiz author, http://www.ctad.co.uk/content/view/191/282/ (accessed September 23, 2007).

[11] SMS quizzes, http://portal.m-learning.org/sms_quiz.php, (accessed September 23, 2007).

[12] Goh, T. T., Kinshuk and Lin, T. (2003). Developing an Adaptive Mobile Learning System, In Proceedings of the International Conference on Computers in Education (ICCE 2003), Hong Kong, 2003, pp. 1062-1065.

[13] Shahreza, M.S. (2006). M-Quiz by SMS, In Proceedings of the Sixth International Conference on Advanced Learning Technologies (ICALT 2006), Kerkrade, The Netherlands, 2006, pp.726 – 729.

[14] Wagner, E. (2007). Mobile Learning: The Next Step in Technology - Mediated Learning. http://www.clomedia.com/content/templates/clo_article.asp?articleid=1686&zoneid=182 (accessed July 10, 2007).