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MILE: Mobile Intelligent Learning Environment—A Conceptual Framework for mLearning*

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In recent years the fast growth of mobile technologies has opened up new opportunities in CAL (Computer Aided Learning)—mobile learning and mLearning. Although still in its infancy, mLearning is taking off very fast as it gives both teachers and learners the 'true' freedom of space and time. It also provides a new way of interaction for teaching and learning. This paper reviews the state-of-the-art of mLearning technology, underlines the potential of mLearning, and discusses the appropriate use of mLearning. Finally, it introduces a Mobile Intelligent Learning Environment or MILE, a conceptual framework for an authentic mLeanrning situation, explains its system architecture and describes the various pedagogical features implemented in this framework.

Keywords: mobile learning; CAL; e-Learning; learning paradigms

INTRODUCTION

COMPUTER AIDED LEARNING (CAL), which has been in use in teaching and learning since the 1980s, is basically an information technology based system used for educational purposes. Traditional CAL resources primarily consisted of tutorials, which are essentially computer-based forms of "programmed instructions". Since its inception, CAL has evolved with the augmentation of different peripheral technologies such as Artificial Intelligence, Internet Technology, Distributed Computation, etc. Owing to the wide availability and popularity of the Internet and advance in Worldwide Web technology in the last decade, a new dimension has been added to the original CAL system; this is known as Web-based CAL or eLearning. Web-based learning or eLearning has generated a great deal of interest from the educators around the world and made teaching and learning possible "anytime", "anywhere" as long as an Internet connection is available. Khan [1] identified the following key features of Web-based learning environments: interactive, device–distant–time independent, globally accessible, distributed, learner-controlled, convenient, environmentally friendly, non-discriminatory, cost effective, etc. Although the benefits of a Web-based educational system are many, Kinshuk *et al.* [2] warned that "the freedom and flexibility offered by the Internet can, however, turn into an extensive waste of time, effort and resources", if there is no sound pedagogical model entwined with this system. Bloom [3] demonstrated that one-on-one tutoring is the most effective mode of teaching. Individual tutoring in a classroom setting incurs financial and logistical problems, whereas eLearning can provide a cost-effective environment for individual tutoring that is independent of time and space constraints.

Recently, with the development of feature-rich mobile phones and other handheld devices, a new way of teaching and learning has emerged—mobile learning or mLearning. mLearning offers a greater flexibility than eLearning's original "anytime" and "anywhere" capability, but has serious constrains in displaying large content. Quinn [4] defined mLearning as "learning through mobile computational devices". Chabra et al. [5] perceived mLearning as "the ability to receive learning anytime, anywhere and on any device". mLearning offers both students and teachers the opportunity to interact and gain educational material through mobile devices independent of time and space. In fact, mLearning is not a new concept; it is an evolution of eLearning that offers greater flexibility and mobility.

The aim of this paper is to describe how mobile computing combined with Internet technology and various well-established learning theories introduces a new way of teaching and learning—mLearning, and to underline the potential of mLearning. The next section reviews the state-of-the-art in intelligent learning environment for both eLearning and mLearning. The paper then focuses on the different learning theories and pedagogical models and how they can be applied in the mLearning settings. The last sections discuss the functional architecture and various pedagogical models of MILE and describe some related work

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carried out in the mLearning area, along with some concluding remarks.

WEB-BASED INTELLIGENT LEARNING ENVIRONMENT AND MLEARNING

The Web-based Intelligent Learning Environment (WILE) is not a new kind of educational approach; rather it has evolved from the traditional Intelligent Tutoring Systems (ITS), which appeared as a new branch of traditional CAL during the late 1950s and early 1960s with the advances in Artificial Intelligence (AI) technology. The Intelligent Tutoring Systems (ITS) typically consist of an internal model of expert knowledge, the learner's current knowledge and the pedagogical principles. As the learner proceeds, the model of the learner's knowledge and the model of the expert's knowledge are compared and, using AI, the sequence of instructions is dynamically generated to suit the needs of the learner [6]. Figure 1 shows the functional model [7] of an ideal ITS.

Measuring the student's knowledge about the subject matter is a key challenge for any computer aided learning (CAL) system, and mLearning is no exception. In order to meet this challenge in an mLearning environment, a modified WILE system is needed. In the case of mLearning, some changes in the communication modules are needed as the learners access the system through a mobile device. A few attempts have been made to develop adaptive tutoring systems in the mLearning context, such as VocaTest [8]—an Intelligent Tutoring System for Vocabulary Learning using the "mLearning" Approach.

In an ideal mLearning environment, we need a mobile device with an Internet connection, Web server hosting learning materials and a database to record learners' profiles and other relevant information. Currently a few technologies are available, including GSM, GPRS (2.5G) and 3G (UMTS, W-CDMA, EDGE, etc.), which provide Internet connectivity for a mobile device. The most widely used protocol is currently the Global System for Mobile communications or GSM. With three variations in protocol (GSM 900, GSM 1800 and GSM 1900) and two combinations of protocols (dual-band and tri-band), it enables users to travel extensively and use the same mobile phone for

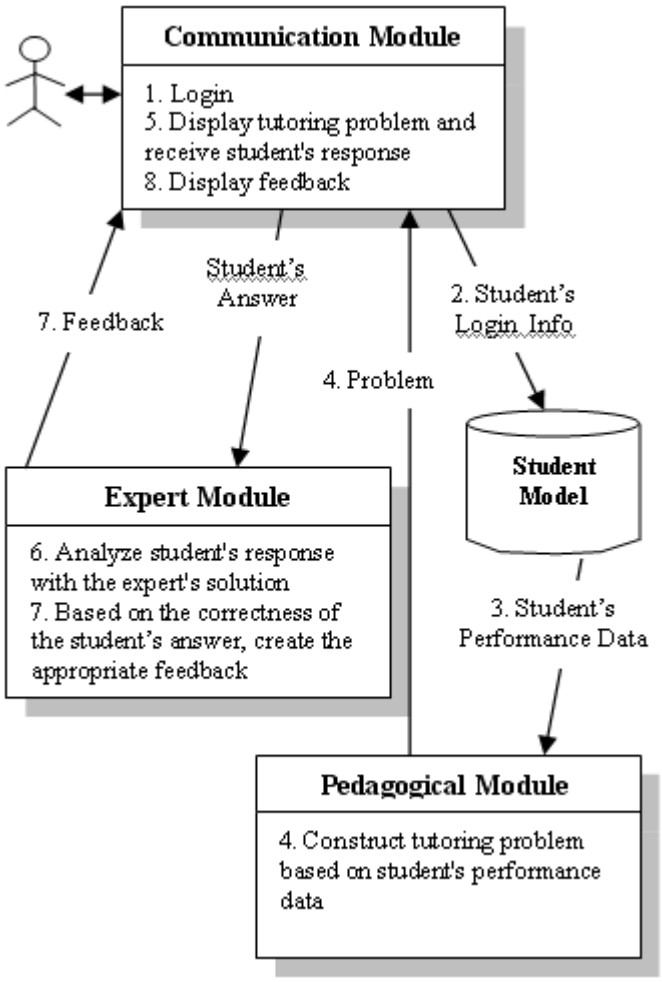

Fig. 1. Functional model of an ideal ITS.

calls, Internet access and mobile telephony services. But the slow data transfer rates offered by GSM (9.6 kbps) may not suitable for mLearning. General Packet Radio Service (GPRS) enabled networks offer 'always-on', higher capacity (30 to 100 kbps), Internet-based content and packet-based data services. This enables services such as color Internet browsing, e-mail on the move, powerful visual communications, multimedia messages and location-based services. The newer technologies such as Universal Mobile Telecommunications System or UMTS, W-CDMA and EDGE are the third generation (3G) mobile communication systems. 3G offer support for a wide range of voice, data and multimedia services. This technology is capable of data transfer speeds of up to 2 Mbps. Most, if not all, of the mobile network operators provide Short Messaging System and Multimedia Messaging System that also play a big role in mLearning.

One of the most crucial challenges of mLearning is the usability of the mobile devices through which learners access the content. The new generation mobile phones and handheld devices have more memory and bigger display areas, but are still not suitable for accessing existing eLearning content. In a generic mLearning situation, learners with mobile devices usually have some fragmented leisure time period for learning activities. Therefore, mLearning content should be short in sessions, challenging and entertaining in order to keep the learners engaged. Recent studies [9] show that PDA-based (Personal Digital Assistant) quizzes are more efficient than the Paper–Pencil-based quizzes. Learners complete the PDA-based quizzes in less time than they complete the same set of quizzes in a Paper–Pencil approach.

mLearning content can be standalone, coming from Web server or mixture of the both. Content should be developed in such a way that most of the mobile devices, if not all, can support. To achieve the maximum compatibility for content, Java is a good tool of choice for developing mLearning applications as most of the mobile phones and devices are now Java enable.

LEARNING THEORIES AND PEDAGOGICAL MODEL FOR MLEARNING

Existing eLearning and mLearning solutions are mainly technology and content driven; they do not pay enough attention to the learner's learning process and to the cognitive mechanism of human learning. But "Learning . . . is not making deposits in one's data bank. It is more like mixing a new ingredient into the soup of perception and cognition." [10]. Therefore the need for an effective pedagogical model that can be applied in the mLearning context is essential in order to make this technology useful in teaching and learning. To develop an effective pedagogical model for mLearning, one must understand both the learning theories and the characteristics of the mLearning environment.

Based on the well-established learning theories, Naismith et al. [11] identified six essential components that a typical pedagogical model should have when designed for mLearning context: (1) Behaviorist, (2) Constructivist, (3) Situated, (2) Collaborative, (5) Informal and Lifelong, and (6) Learning and Teaching Support.

1 Behaviorist Learning Model: According to the behaviorist learning theory, learning occurs when new behaviors or changes in behaviors are acquired as the result of an individual's response to stimuli. The influence of the external environment contributes to shaping of the individual's behavior. They use mobile devices to present learning materials, obtain responses from learners, and provide appropriate feedback; this fits within the behaviorist learning paradigm.
2. Constructivist Learning Model: In constructivist theory, learning is the process whereby individuals construct new ideas or concepts based on prior knowledge and/or experience. Within a constructivism learning framework, instructors encourage learners to discover knowledge for themselves. In order to transform learners from passive recipients of information to active constructors of knowledge, mobile devices allow them to work with simulations of different concepts, problems or situations.
3. Situated Learning Model: The situated learning paradigm was first expounded by Brown *et al.* [12] that drew heavily on the work of renowned researchers such as Vygotsky, Leontev, Dewey and Lave. In proposing their model of situated cognition, Brown *et al.* [12] argued that, contrary to many existing teaching practices that abstract knowledge from context, meaningful learning will only take place if it is embedded in the social and physical context within which it will be used. Situated learning requires knowledge to be presented in authentic contexts and learners to participate within a community of practice. mLearning can fulfill both these requirements by providing different types of appropriate context-based learning environments such as problem-based learning, case-based learning and context-aware learning.
4. Collaborative Learning Model: The focus of the collaborative learning model is on developing a collective knowledge base and enhancing learners' problem-solving skills. Collaborative learning can extend learners' cognitive ability and enable learners to build their own interpretations [13], and support, guide and extend the thinking process [14]. mLearning can provide learners with different types of collaborative learning environments such as online chat and asynchronous threaded discussion board.

5. Informal and Life-long Learning Model: Learning happens all of the time and is influenced both by our environment and the particular situations with which we are faced. With the rapid development of mobile content, mobile devices are playing an important role in this learning model.
6. Learning and Teaching Support: Besides supporting learning activities, mobile technology can also support in-classroom management. Teachers can use mobile devices to report attendance, record and review student grades, gain access to school data, and effectively manage their own schedules. In higher education, mobile devices can even be used to provide course material to students, including assignment due dates, and information about schedules and room changes.

Silander *et al.* [15] introduced a new pedagogical model for mLearning situation called AEFIRIP, which is based on the contemporary learning theories and pedagogical models of eLearning, such as Progressive Inquiry [16], Activating Instruction [17] and Problem Based Learning [18]. AEFIRIP also provides the Mobile-CSCL (Computer Supported Collaborative Learning) facility, which relies on socio-cultural learning theories [19].

MILE: MOBILE INTELLIGENT LEARNING ENVIRONMENT

MILE (Mobile Intelligent Learning Environment) is a conceptual framework for an authentic mobile learning environment. An authentic learning environment provides students with authentic activities or real-life learning experiences—a learning environment where conditions, characters, circumstances and parameters are drawn to simulate the real-life context for learning. In recent years the use of authentic activities within the online learning environment is on the rise and has been shown to have many benefits for learners [20]. Based on a wide literature review, Herrington *et al.* [20] identified ten major characteristics of authentic activities—most of these ten characteristics such as collaboration, reflection, seamless assessment, investigations, etc. can be found in the MILE framework.

A blended pedagogical model that contains most of the components described in the previous section have been chosen for MILE in order to provide a complete learning environment for both teachers and learners to meet their learning need while both of them are 'mobile'. The aim of this framework is to provide a generic guideline for educators who like to explore the potential of mLearning. The partial implementation of this framework has been adopted in VocaTest [8].

Basically MILE is a Java based client–server application, where the client program is a Java MIDlet running on Java-enabled mobile devices and the server program is a set of Java Servlets running on a Tomcat server. There is a student model database that records students' performance data implemented in MySQL and connected with server through JDBC. There are two sets of client programs—one for learners to participate in various learning activities and the other for teachers to monitor the learners' progress, participate in forum discussion, disseminate important notices, etc. Client program communicates with the server through GPRS and SMS technology.

When the teachers or learners start the MILE client application resides on their mobile phones or PDAs in a spontaneous learning situation, he or she has to log in with the user id and password. MILE MIDlet will open a URL connection to the login servlet residing in the server for the authentication process. Upon successful authentication, teachers and learners will be brought to the respective client program. In the learners' case, they will have the following fivedifferent types of learning activities:

1. Browse the learning materials: Obviously mobile devices are not fit for reading long text materials and the mLearning situations do not allow learners to read long materials as well. The reading materials designed for MILE are bite-sized and can be fetched from the server side. Bite-sized learning materials prepared by the teachers are arranged in a well-defined adaptive sequence based on the learning style of a particular learner. The basic learning theory behind this way of browsing the learning materials is behaviorism.
2. Interact with simulation: Learners can construct their own knowledge through interacting with simulations of a particular concept. In MILE, learners can interact with a simulation of a crank-shaft; they can observe the change in angular velocity of the crank-shaft by changing the length of the shaft. This activity is based on the constructivism theory. Owing to the limitation of the processing power of currently available mobile devices, developing large-scale simulations is still a big challenge.
3. Data collection and upload: Learners can collect data from their lab experiments or field-trips and upload these data through MILE client interface to the server. This kind of learning activity is based on the situated learning theory.
4. Doing a quiz: In MILE, whenever the learners start a quiz session for a particular topic, the server program fetches a set of quiz questions from the database according to the learner's current level of knowledge about the subject matter. Quizzes can be of different types, such as (1) Checkbox questions (single and multiple choices), (2) Order questions (where students order the questions in the correct sequence) and (3) Fill-in questions. When the learner has

finished the quiz session, the client program will send the performance data to the server side so the learner's current level of knowledge can be updated. This activity is based on the intelligent tutoring system architecture.

5. Participate in discussions: Collaboration with peers is one of the important components of the active learning process. In MILE, learners can participate in a discussion board together with their peers and teachers. They can post a question, reply to a question posted by someone else or simply browse through all the posts. Participating in the discussion boards encourages critical thinking and reflection as learners post questions and respond to others' postings.

The teachers' interface in MILE is quite different from the learners' interface. Basically the client program for the teachers consists of a set of class management tools:

- Monitor learners' progress: Teachers can monitor the progress of the whole class from their performance data and easily identify the learners who are at risk.
- Participate in discussion: A teacher's participation in the discussion board is important as he or she can play the role of moderator of the discussion. Sometimes learners can't reach the right conclusion or answer a particular topic or question, so a teacher's intervention is very much needed in that situation.
- Disseminate important notices: At times teachers need to disseminate important notices to their students. MILE has a functionality such that teachers can quickly deliver any urgent messages such as the postponement of a class or change of classroom to their students.

Thus MILE implements various learning theories under one single environment. MILE does not attempt to replace the regular classroom teaching and learning, rather it attempts to supplement areas where and when regular teaching and learning fail to contribute much.

RELATED WORKS AND CONCLUSION

mLearning has been studied for last few years and so some progress has been made by many research units [21–22]. Work has also been done to design and implement new pedagogical models appropriate for mLearning settings. The advantage of the MILE system is that it provides a broad range of activities for both teachers and learners based on various cognitive learning theories.

Although still in its infancy, we believe that mLearning will find an appropriate niche in the teaching and learning paradigm for certain learning situations such as spontaneous learning in fragmented time-slots. The biggest challenge to bringing mLearning to the frontline would be learning content and activities.

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