Applications and frameworks for m-Learning in Mathematics

Atul Purohit[1], Navdeep Bhatia[1] and Subramanian Arumugam[1]
Guided by: Prof. Jennifer Wong & Prof. Anita Wasilewska

[1]State University of New York at Stony Brook, NY 11790, USA
Email: apurohit@cs.sunysb.edu, navbhatia@cs.sunysb.edu, sarumugam@cs.sunysb.edu

The rapid change in technology in the 21st century is changing the way we observe the world around us. Integration of computer with education opens new dynamic and adaptive learning paradigms for education. M-learning emerges as a major subset of e-learning which provides just-in-time adaptive learning solutions which may be used complimentary with the traditional education in classrooms. Architectures and frameworks are proposed for making mobile applications more modular and device independent. Three case studies for m-learning in mathematics are done for m-learning initiatives taken in different parts of the world and analysis is done for each of them.

***Index Terms*—M-learning, mobile phones, mathematics, mobile applications, architecture**

I. Introduction

With the advent of 21st century, technology replaced many traditional aspects of our lives. It changed the methods of communication, altered the phenomenon of mobility and had a great impact on reducing the round world to a flat world. It had an unprecedented impact on the way education was perceived. Education incepted from pictography and hieroglyphs in early 2000 BC and evolved to books with the discovery of printing press. With the evolution of internet, books were digitized and a new era of e-learning began. E-learning is education – anywhere, anytime. With the portability associated with computers, scholars can now sit in their houses or be on a move while watching the podcasts and videocasts of their professors. This may also help educate people who have access to infrastructure but not enough tutors available.

One of the emerging dimensions of e-learning is m-learning. In principle, m-learning is a subset of e-learning which deals with learning through a mobile phone. With a mobile phone, comes the flexibility and mobility which traditional e-learning applications can't provide while it compromises on the speed, processing power and the vast number of applications which e-learning provide.

This survey paper tries to analyze the change in learning methods while adapting to electronic learning. It analyzes a framework adopted for mobile learning. We also analyze a device independent system architecture for adaptive mobile learning. A study of role of m-learning in Africa is scrutinized so as to gather a broader perspective on the e-learning in some underdeveloped parts of the world.

In the later part of the survey paper we take three scenarios in which m-learning is used for teaching mathematics to students – a group of kindergarten kids, students in a primary school in Malaysia and eight grade students in a school located in Southeastern Ohio.

The objective of this paper is to analyze the various m-learning initiatives taken for mathematics along with the architectures and the frameworks used.

II. Mobile Learning – Architectures and Frameworks

The number of internet users in the world is approximately half to that of the number of mobile phone users [1]. This number of mobile phone users is expected to rise to a whooping 6 Billion figure by 2013. The major advantage associated with mobile phones is the affordability and portability. With the increase in the number of mobile phone users, there is a tremendous increase in the number and types of applications for mobile phones.

In [2], a framework is proposed for m-learning. This framework comprises of a layered and modular structure which enables a layer to be built on top of the functionalities provided by other layers.

Mobile learning applications
Mobile user infrastructure (browser, handheld devices)
Mobile protocol (adoption of content with WAP)
Mobile network infrastructure (cellular systems, satellites, etc)

Figure 1. Mobile learning framework taken from [2]

The first layer of the proposed framework insists that mobile applications should enable in-time delivery of information from automated servers and use this information for learning without use of other people and make learning adaptive. For all the services like video-on-demand, text based solution etc. the mobile phone should meet all the specifications regarding memory, display and processing power. One of the major challenges in mobile phones is to integrate it with the vast information present in internet. Many WAP protocols are developed which try to minimize the differences between a mobile phone and a personal computer. Many languages and mobile browsers like XML and Safari are built specifically for this purpose. Many website administrators are also considering the significance in growth of mobile phones in the recent past and making a mobile version of their applications. Apart from making the cellular phone a better device, emphasis should also be given on

making network user infrastructure better in terms of providing seamless connectivity and value added services like roaming, EDGE and GPRS.

There are many advantages of mobile learning using this modular approach. Apart from being helpful for mobile phone application developers it also proves useful to the end user. On-the-fly information helps in making the application dynamic and adaptive. One of the major changes it brings lies in information management and distribution. In traditional information systems (such as education in classrooms), most of the information is delivered according to the need of average user. In adaptive learning, learning trends for each user is analyzed and information is given as per need of each user; hence helping in better information management.

A similar attempt to bridge the divide between mobile learning and traditional methods of learning is done in [3]. A device independent system architecture for adaptive mobile learning is proposed in [3] which inherits some of the key aspects of [2]. It is quite evident that unlike computers, there is a huge variation in the models/specifications of mobile phone devices. So it is extremely hard for application developers to develop m-learning solutions for mobile phones [4] [5] [6]. There is a absence of applications which provide real-time adaptive learning. The architecture in [3] provides the user with adaptive information by merging the learners social network profile (such as facebook, blogs etc.) with the user's personal profile on the phone's application.

The proposed architecture consists of detecting the user's and the phone's information. Using these two, adaptive information is presented to the user which will work on the user's phone and be suitable to the needs of the user.

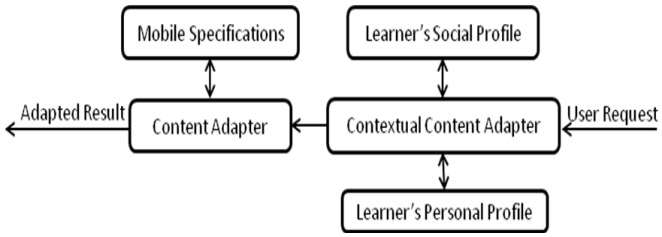

Figure 2. Flow Diagram for [3]

The *Content Adapter* detects the phones information using a device detector which determines the amount of memory, processing power and browser information which are necessary for information formulation. It also gathers information about the size of screen, image formats supported and different mark up languages like XML, HTML, DHTML supported. Meanwhile the *Contextual Content Adapter* analyzes the personality of the user by integrating the user's information with different social networking sites. Combining both the *Content Adapter* and *Contextual Content Adapter*, the users learning ability is determined by keeping both his past as well as present learning skills, then the phones specifications are matched with the requested information and an adaptive solution is presented to the user.

Both these approaches in [2], [3] provide the user with the information which the user needs in the format which is most suitable for his need while keeping in track of the phone specifications.

Using these applications frameworks and architectures, one can build mobile phone applications that help a student to learn adaptively. Various tests have been carried in various parts of world to test the usability of such applications with different categories of audience.

III. Mobile Learning – Application And Initiatives

One such place where m-learning applications are being deployed is Africa [7]. Most of the African countries have a long history of civil wars and political instabilities [8]. There are not enough infrastructures for majority of learners in Africa. To the contrary, the rate of new mobile and wireless phones in Africa is amongst the highest in the world. This may be due to the fact that establishing wired connectivity for distant villages and town is more difficult than establishing a wireless connectivity. The paper [7] conveys that traditional form of institutional learning involves transfer of information from the teacher to the student. It hardly creates new information or knowledge. If proper pedantic methodologies are not implemented in studies, it can prove to be one of the serious drawbacks of institutional learning. E-learning tries to bridge the gap which traditional teaching provide in school by giving a vast variety of information to the student.

In countries like Africa where number of mobile phones are increasing at a very high rate (approximately a triple digit growth rate [7]), switching from e-learning to m-learning can deliver better results in terms of productivity per unit investment.

The University of Pretoria launched an initiative towards mobile learning in 2002 in Africa. They made sure that nearly all the students involved in the program had a mobile phone. The project got a head start in November 2002 when bulk messages were to each student focusing on reminders such as exam dates, registrations etc. It had two major advantages: It reduced the cost of postal services required for reminders such as exam dates and schedule. Furthermore, it also reduced the time required by conventional methods of transmission of data.

Later using the data obtained from 2002, a couple of initiatives were taken in 2003and 2005. In 2003, more emphasis was given on giving computer literacy to people. Computers were placed in community centers where people could access them. Later in 2005, mobile applications were developed which enabled a mobile phone user to download course material using GPRS, EDGE and other emerging mobile protocols. A timeline diagram along with the achievements is given in Figure 3.

While mobile learning was always thought to be a successor of e-learning, it actually paved a way for e-learning in Africa. By using mobiles phones, people were not only taught their coursework but also they were educated in information and communication technology. With the increase in the wireless connectivity and decrease in the cost of mobile phones, information and communication technology literacy will

increase at a much rapid rate in Africa.

As M-learning applications were also being developed for Africa, the trend for the same was setting up in several different parts of the world as well.

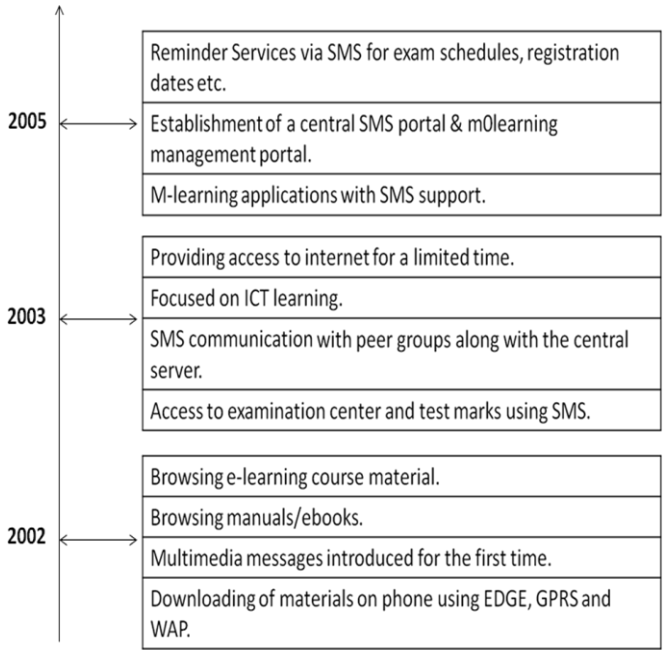

Figure 3. Timeline for m-learning initiatives taken in University of Pretoria in Africa

One such adaptive learning system was developed for kindergarten's mathematics teaching [8]. It was conducted in two stages: the first one to determine the student's behavior towards questions and second one to make an adaptive learning solution.

In the first approach, groups of children were formed which were asked to perform simple geometric pattern matching questions on a PDA. In the second stage, an adaptive solution was developed on a touch screen PDA. The PDA was connected to a central wireless server which provided the next question based on the answer to the current question. The whole experimental setup was very simple and the use of PDA was very intuitive and easy owing to its touch screen features.

After conducting the experiment for the second phase, it was found out that people with lesser skills were performing as par with the people with average skills. This was quite an important achievement as it would enable all the students to receive the same educational opportunities in the future. It also strengthens that m-learning or e-learning helps people understand better and it helps the people with lesser skill the most.

It was also learned that although m-learning was fun, but people generally get tired after some time and then their performance starts decreasing. Some modifications in the applications are needed which can cope up with the change in difficulty level due to a tired user. One option is to make the user interface more intuitive. But this option can only stretch the time duration after which a person gets tired. Modification in the contents of the application after a particular time can make the application more involving. One more option is to involve more subjects after a particular time.

A similar experiment was carried out in a primary school in Malaysia [9]. This initiative was taken by the government of Malaysia as one of its seven flagship applications in which smart schools were established where conventional studies are complimented with m-learning.

The implementation of 'Mobile Math' was carried out for students of standard 5 and 6. Students were tested on mobile phones using quizzes and tests and the results were interpreted using automated graphs. The architecture of the application was developed using Alykko project of Silander and Rytkonen [10]. A browser based solution was developed which works on both browsers on PC and a mini-browser in mobile phone. The connectivity between mobile phone and PC was established using a WAP gateway. The entire application is developed using WML, PHP, XHTML and MySQL.

One unique contrasting feature that this application had with the pervious implementation for the primary school was that its user interface was tilted towards functionality rather than being attractive. The simplicity of the application interface also makes it more instinctive and helps a non-technical person to access it with much ease.

The application works in the following way: The teacher posts a quiz/test of different category and difficulty level and gives the students login ID. The questions in the test can be randomized as per need. The student logins into the system using the login ID and answers the quiz. The application then prepares charts/ performance analysis for the student and shows it to the teacher/student.

The application was rigorously tested for various scenarios. Students from 20 primary schools were randomly selected irrespective of their mathematical skills. The groups were then divided into two and each of them was taught three lessons followed by quizzes in a span of 2 weeks. One of the groups was given conventional paper based quizzes and the other one was given quizzes using 'Mobile Math'.

After two weeks, a multiple choice paper based test was conducted for both the groups. As expected, the results of the people who learned using the 'Mobile Math' application outscored the other group by quite a margin.

Another such experiment with mobile learning was done in a school in Southeastern Ohio in USA [11]. Students living in developed countries like USA are familiar with emerging devices such as iPod.

Two classes of eight standards were selected from the school. All the students of these classes had some prior knowledge of using iPods as they had previously worked on a similar experience using palm. The classes had a mixture of students – from good to not so good.

Apart from giving iPods to students, the classrooms were equipped with iMacs. For three weeks, students were given well prepared lectures in mathematics along with videos and movies complimenting them. After each week, there was a gap of one week in which use of iPod was not compulsory but it was left on the student to use it or not.

The students were asked to keep a log in which they wrote about their daily experiences of using the iPod. It was noted if a student uses his iPod even when not asked to do so. A short survey was also taken from instructors and students about the ease with which they used technology in mathematics.

All the comments of students and instructors were noted and inferences were drawn from them. As speculated, it was more fun than learning for students. Some of the students even commented that even in their free time they were learning something from the iPod given. Instructors also found that using iPods proved to be very helpful to them. They considered the movies as an added advantage as it made their task easier.

IV. Analysis of Frameworks and Applications

"*If we teach today as we taught yesterday, we rob our children of tomorrow*" – John Dewey.

John Dewey summarized entire need for e-learning in one sentence. Education today is not perceived as a medium by which an instructor imparts his knowledge to students. It has evolved to a much broader sense where students have access to information from all around the world. Evolution of internet from its primitive form has flattened the world. A user can simply log in to libraries across the world and gather all the information which he wants. The need of the hour is to build information management systems which provide accurate information to the user in an easy and timely manner.

Learning applications built over traditional internet are widespread and provide a large amount of information in comparison to the learning applications built for mobile phones. However, the rate of increase in the number of computer users is slow in comparison to the increase in the number of mobile phone users.

Applications for mobile phones can be made using the two architectures described earlier in the paper. As the architectures are modular, it's easier to make applications using them. Mathematics is a subject which cannot be excelled by a student unless and until he has interest in it. M-Learning looks promising to play a major role in developing this interest among the students. All the three scenarios where mathematics is taught with the aid of m-learning deal with high end mobile phones or PDAs. Care should be taken to devise the applications in such a way that most mobiles phones, whether low and or high end can handle all the operations. The device independent architecture provided in [3] provides a nice solution to such problems. But even in that case, it may happen that a mobile phone can't handle the software required for the *content model*. Care should be taken for such cases.

Figure 4 contains the comparison between the three different approaches used in [8], [9] and [11].

In areas like Africa where electricity is scarce and establishment of wired network is proving to be cost-inefficient, mobile phones are proving to be a boon. Owing to the relatively cheaper costs of mobile instruments and ease in installations of wireless networks, use of mobile phones is increasing. Use of mobile phone also adds to mobility and just-in-time service. One of the key advantages that mobile phone provides is the in-time synchronous audio delivery in worse network conditions. It is one of the features which even a computer fails to provide in low bandwidth situations.

	Kindergarten mathematics teaching	M learning in primary school in Malaysia	Mobile Math in USA
Device Used	Compaq iPaq PDA	HP iPaq PDA	iPod
Target Audience	Six years old	Eleven years old	Twelve years old
Subject Taught	Mathematics	Mathematics	Mathematics
Features	-Adaptive Learning -Game oriented rather than quiz oriented	-Non adaptive but keeps track of progress and hence instructor can change the set of questions -Quiz /test oriented -Low end basic GUI which helps the non-technical user -Features of announcements/ posts by instructor	-Teachings complimentary to classroom studies -Extensive use of movies and presentations
Interpretation of results		-Automated generation of graphs and progress reports	-logs from students/instructor are analyzed by hand -surveys and comments from students/instructor
Feedback from users	-Lower skilled people found it more useful -GUI should be made more user friendly so as to reduce fatigue after long hours of playing	-Users using the application outperformed the users not using it in a paper based test	-No separate test conducted for the students. -Story based approach was really fruitful for students although creating stories might not be possible for all parts of mathematics -Achievement of more clearer understanding of concepts

Figure 4. Comparison of various m-learning initiatives in [9], [10] and [12]

V. Conclusion

Mobile phones provide a promising future in e-learning to make it even more widely available and accessible. It has the ability to further expand the way we learn. Learning with mobile phones becomes fun as well as an intuitive way of study which enables to open new horizons in new information generation rather than just transferring of knowledge.

Conventional classroom can never be replaced by m-learning. It is also evident that mobile phones can't be used as the primary way of teaching, but they can certainly be added to the conventional methods of teaching to make it more effective and to improve the quality of education. Our main emphasis should be on providing a better knowledge management system which enables a person to gather as much information as he wants without burdening him with information which he doesn't need. More challenges lie ahead in terms of development of simpler and more modular applications which can be run on any mobile phones irrespective of the memory and processing constraints. Another area that needs to be looked into is the user friendliness of the mobile applications. A better user interface does not only make the application better but also creates interest in the user.

To make m-learning as an integral part of teaching, instructors need to be trained to skillfully make use of the advancements in mobile technology. Technology can aid us to help deliver better information; it is only upon us to determine how we can maximize the use to technology for a better knowledge system.

As correctly summed up by Keagen in his book - "*The challenge for distance systems at the dawn of the third millennium is to develop didactic environments for mobile phones and mobile computers as the availability of the mobile devices spreads to a billion users. The mobile telephone is becoming a trusted, personal device with internet access, smart card usage, and a range of possibilities for keeping the distance students in touch with the institution's student support services, in contact with the learning materials and fellow students, while at home, or at work, or travelling.*" [12]

VI. References

[1] F. Muller-Veerse, "Mobile commerce report," *Technical Report*, Durlacher Research Ltd, London 1999.

[2] Chi-Hong Leung; Yuen-Yan Chan, "Mobile learning: a new paradigm in electronic learning,", *Advanced Learning Technologies*, 3rd IEEE International Conference, vol., no., pp. 76-80, 2003.

[3] Xinyou Zhao, Toshio Okamoto, "A Device-Independent System Architecture for Adaptive Mobile Learning," *Advanced Learning Technologies*, Eighth IEEE International Conference on Advanced Learning Technologies, pp. 23-25, 2008.

[4] Kojiri, T., Tanaka, Y. & Watanabe, T. (2007). "Device-independent Learning Contents Management in Ubiquitous Learning Environment," In T. Bastiaens & S. Carliner (Eds.), *Proceedings of World Conference on E-Learning in Corporate, Government, Healthcare, and Higher Education*, pp. 991-996, 2007.

[5] Meng-Chien Yang, "An Adaptive Framework for Aggregating Mobile Learning Materials," *Advanced Learning Technologies*, Seventh IEEE International Conference on Advanced Learning Technologies, pp. 180-182, 2007.

[6] Motiwalla, L. F., "Mobile learning: A framework and evaluation," *Computer Education* 49, pp. 581-596, 2007.

[7] Tom H. Brown, "The role of m-learning in the future of e-learning in Africa," 21st ICDE World Conference, Hong Kong, 2003.

[8] Roessler, P. G. , "Political Authority and Civil War in Africa," *The International Studies Association 48th Annual Convention*, Hilton Chicago, CHICAGO, IL, 2009.

[9] Ketamo, H., "mLearning for Kindergarten's Mathematics Teaching," *In Proceedings IEEE international Workshop on Wireless and Mobile Technologies in Education*, M. Milrad, H. U. Hoppe, and Kinshuk, Eds. WMTE. IEEE Computer Society, Washington, DC, pp. 167-168, 2002.

[10] Saipunidzam Mahamad, Mohammad Noor Ibrahim, Mohamad Izzriq Ab Malek Foad, Shakirah Mohd Taib, "Open Source Implementation of M-Learning for Primary School in Malaysia," *World Academy of Science, Engineering and Technology*, Volume 44, pp 752-757, 2008.

[11] Franklin Teresa, Peng Li-Wei., "Mobile math: math educators and students engage in mobile learning," *Journal of Computing in Higher Education*, Volume 20, Issue - 2, pp. 69-80, 2008.

[12] Keegan, The future of learning: from E-learning to M-learning, Hagen: Fernstudienforchung, Germany.