

Where is Mobile Learning Going?

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Abstract: M-learning is a quite new, exciting and promising field. Papers on this domain are spread through several conference and workshops proceedings, so it is rather difficult to have a complete view of the field. This paper aims at helping, by reviewing the existing work, and classifying the research directions that try to answer the questions of *how* m-learning will help reaching the goals of a better learning, and *how* it will be different from the rest of e-learning. Finally, we try to foresee some directions for successful m-learning research.

Introduction

Computing technology has been applied to learning since decades, but it has really flourished with the advent of the Web. In recent years the quick growth of mobile technologies is promising a new revolution that might be comparable with the Web. The forecasts are (Steinberger 02) that by 2004 about 63 millions handhelds will be sold, and that approximately 38% of them will be smart phones, integrating PDA functionality with features for communication. And the forecasts are already getting true (Scott 02) – since according to DoCoMo more than 37% of Japanese population owns Internet-capable phones. More and more mobile devices with improved capabilities are appearing on the market. Lots of mobile clients already support Java (J2ME) making it easier and less costly to develop portable applications.

Mobile learning (m-learning) is a field which combines mobile computing and e-learning. Will e-learning undergo a revolution like it happened with the Web? We do not know, but we must try to answer the question, by trying to imagine how mobile devices can enhance e-learning or modify it. Many people are working in this new field, and it is increasingly difficult to have an overview of what is going on, since most papers are dispersed in many conferences, and some reports are only available as gray literature. In the present paper, we present an overview of what is going on. By no means were we able to discover all the interesting papers that have been published in the field, but from the inevitably partial view we try to let emerge the trends that characterize the field.

Defining M-Learning

There is a common agreement that m-learning is e-learning through mobile computational devices. In general by mobile device we mean PDAs and digital cell phone, but more generally we might think of any device that is small, autonomous and unobtrusive enough to accompany us in every moment in our every-day life, and that can be used for some form of learning. We shall begin by enumerating the different ways such a device can help us. In first place, they can allow to *interact with people*, via voice and through the exchange of written messages, still and moving images. A second possibility is to consider them as tool for *accessing content*, which can be stored locally on the device or can be reached through interconnection. Under the same category we might include *accessing services* that can be seen as dynamically generated content. The functions that are offered by such devices are therefore not different from what can be done with other devices, in the same way as mobile telephony is not intrinsically different from residential telephony, but the change of boundary conditions induces a new use of the media. Also, the different interface that such instruments have (small screen, small or no keyboard) has an impact on what is reasonable, useful and even pleasant to do on such devices. For instance, reading a digitalized book on a Palm is today barely acceptable, and reading it on a cell phone is today a laughable idea. Even browsing the Internet is an experience not comparable with doing it on a PC.

So while some research concentrates on how to *best perform the same action in a changed environment*, some other focuses on *what actions are best suited to new conditions*. On this last aspect, the ability to

contextualize, i.e. of to take into account *where the user is* (in space and time) and *what the user is doing* in order to propose the best suited activity is a big challenge, that goes under many names (the most popular of which are *ambience intelligence, and ubiquitous, pervasive or sentient computing*).

And of course, research on pedagogical use of the new media is a wide open field. On the more technological side, infrastructural research on mobile computing is of great help to m-learning, since many problems in m-learning are in common with *m-anything*.

We shall try to review these different aspects. The rest of the paper will therefore follow the structure we outlined here. We will begin by covering infrastructural research, since that is a common denominator. We then will examine the problem of accessing content from the learning perspective, and we will move to facilitating interaction with other people.

Infrastructural Research

Access to the web through personal electronic devices, with their small screen size, has been an interesting problem for lots of researchers. Unfortunately, today most web pages are designed to be displayed on desktop computers with color monitors having at least 800x600 resolution. This leads to at least 2-to-1 (often greater) ratio of designed vs. available screen area, making direct presentation of most pages on the small devices aesthetically unpleasant, un-navigable, and in the worst case, completely illegible. Work is being done in the area of device independent access to web content. In this context different approaches are proposed for describing device capabilities (HTTP Request Header, CC/PP, UAPROF, etc.). Also different architectural approaches are developed for using the information of devices' capabilities and adapting the content accordingly. The adaptation could be server-based (XML/XSLT, Cocoon, Axkit), proxy-based (AvantGo, Palm Web Clipping) and client-based (XHTML/CSS). A comprehensive survey of current technologies for device independence and device independence activities can be found at <http://www.hpl.hp.com/techreports/2001/HPL-2001-83.html> and on www.w3.org.

Adapting the content through transcoding servers is one of the often used techniques. The web content is retrieved from the internet by the server and is converted in suitable for the device form. Different transcoding techniques are used for simply translating from one presentation language to another (e.g. WAP-HTML-WAP), for reducing the contents size (Knutsson et al. 02), for satisfying bandwidth or screen capabilities of the devices (Bickmore et al. 97, 99), to adapt the structure of the content in more appropriate logical fragments (Schilit et al. 01; Hoi et al. 03; Yang et al. 02) or to present the content in some symbolic way (González-Castaño et al. 02). Some solutions also face the problems of connection speed and processing capabilities of the devices for delivering streaming media (Shen et al. 03). All these approaches though suppose online access to the content. Only some of the transcoding proxies take care also for caching web pages for offline usage (e.g. AvantGo).

Caching and synchronization are two of the main problems of mobile applications in any domain. Mobile devices are often disconnected because of the lack of access in certain places but also because of the high prices in most of the cases. Two different situations arise – when the device is disconnected on purpose, but the user wants to work and when the connection fails during his work online. Depending on the application and the data needed the requirements of the first situation can be met by using AvantGo or other client-side caching mechanisms (see e.g. Zenith 02). Although thick-clients can be used to maintain the synchronization and the caching there is still the problem of the small amount of memory available on the mobile devices. The data should be carefully separated and only the necessary pieces should be uploaded.

Other approaches provide special services for mobile devices. The delivery approach can be different, such as the Satchel architecture (Lamming et al. 02; Flynn et al. 00), which provides a distance access to documents and other work resources through a special browser or mobile web services could be also used as Microsoft and IBM released versions of Web Services Toolkits for mobile devices. This enables access to Web services on enterprise servers, but although there is a big potential in the Mobile Web Services there are some disadvantages and problems that should be overcome. One of them is the loss of network connectivity – the service is not available if there is no connection and the question how a system should recover from a failed web service stays open. It is also not clear how the services are discovered in peer-to-peer networks and how to manage the resources of the devices. These issues are the objective of research like Microsoft Marlin project (<http://research.microsoft.com/research/sv/Marlin>): Mobile Access to Resources Living In .NET).

Context is observed in variety of fields in everyday and business life that profit from the usage of mobile devices. Solutions for various scenarios are proposed, like personal context storage system (Riché et al. 03), support systems (Cheverst et al. 00; Pospischil et al. 02), location-aware shopping assistant (Bohnenberger et al. 02). A survey of context-aware computing and applications can be found in (Dey 01 and Korkea-aho 00).

Usability of different mobile devices through different activities is also an important issue in multiple domains. Work and experiments are done for improving input usability of the small devices (MacKenzie et al. 01; MacKenzie 02; Sazawal et al. 02), towards improving readability (Öquist et al. 02), displaying multimedial data (Vainio et al. 02; Chisalita et al. 01), etc.

Location discovery can be performed with various techniques. Some systems use the Global Positioning System GPS, but they work only outdoor. Some indoor-positioning systems offer context-aware services: the Active Badge System (Want et al. 92) and WIPS (WIPS 00) (Wireless Indoor Positioning System) use infrared beacons. Active Bat (Ward et al. 97) uses ultrasonic, the Cricket system (Priyantha et al. 00) is based on a combination of ultrasonic and radio. SpotON (Hightower et al. 00) uses signal strength of radio signals. Some recent research bases the discovery of the position on the wireless signal of Wi-Fi networks.

Accessing Content

Accessing content is generally based on the infrastructural research mentioned above for transforming data into format suitable to mobile devices. Closer to the e-learning domain, then research specializes in adapting courses for mobile devices, and in building learning WAP portals. The most obvious use of mobile devices for educational purposes is in fact a direct application of the e-learning techniques on smaller devices instead on a desktop PC. For grown-up people studying is by default arranged on courses, lectures, classes, etc. A logical sequence is the development and experimentation on transforming traditional courses in a form appropriate for mobile devices.

Ultralab *M-Learning* project (<http://www.ultralab.ac.uk/projects/m-learning/>) is one of the projects that have a special section dedicated on creation of a WAP portal for educational purposes. The technical aspects in the creation of a WAP portal for educational purposes do not differ from a common WAP portal. As the target users for this project are young people (age 16-24) with literacy problems, the group studies the problem of keeping the interest of the young adults to the useful learning materials, by exposing also modish and exciting subjects. Once again the pedagogical aspect of education is observed.

The positive results of many more systems, developed to combine WAP courses and SMS notification systems, were published by different universities in the last couples of years. A few examples of them are *HyWeb* (Jones et al. 02) at Griffith University Gold Coast, *mid-2000* (Virtanen et al. 02) at Minnesota State University and the *NAIT m-learning* project (<http://www.nait.ab.ca/MobileLearning/>) in Canada.

An m-learning project that focuses on the testing of the use of WAP technology in higher education is the *UniWap* project (Sariola 01; Sariola et al. 01; Seppälä et al. 02). The team tries to explore the process of creating an operating environment for studying and teaching through smartphones and WAP phones. The Virtual University needs to support the mobility of the participants of the learning process (the students and also the teachers). One phase of the project was to create some working prototypes (courses modules) and to investigate the problems and the value of such courses. The positive results they encountered (easy to develop, willingly accepted and widely used modules) encourage them to continue investigating the new coming technologies – digital imaging with mobile devices, 3G, etc.

At Ultralab *M-Learning* project the team is producing m-learning materials for people with literacy and numeracy problems (Collett et al. 02; Traxler 02). A great potential is encountered from the cognitive and pedagogical point of view. Learning modules are created by using standard tools (like Macromedia Flash, in version for mobile devices). Once again the preliminary conclusions are that new technologies have great impact on students' interest in the subject studied. In this case this was one of the main wanted repercussions.

"From E-learning to M-Learning" (<http://learning.ericsson.net/leonardo/thebook/book.html>) is a long-time project that aims to create a learning environment for wireless technologies by developing course materials for range of mobile devices. A discussion about the characteristics of the devices that are proper for learning is made when taking the decision what devices to use in the project. An analogy and differentiation is made between e-learning, d-learning (distance learning) and m-learning and in this context they try to foresee the future of m-learning and the methods and technologies that should be used for successful m-learning.

In the attempt to find the best way to apply mobile devices in education people are experimenting with different fields: one of them is language learning. At Stanford Learning Lab (SLL 01) an exploration of m-learning has been done by developing prototypes that integrate practicing new words, taking a quiz, accessing word and phrase translations, working with a live coach, and saving vocabulary to a notebook. They envisioned that a good approach would be to fill the gaps of time by short (from 30 seconds to 10 minutes) learning modules in order to use the highly fragmented attention of the user while on the move. The research indicates some very useful directions, like the length of the learning materials, the personalization of interaction and the frustration of the user and the

decreasing of the perception of the learning materials because of the poor technological implementation (i.e. poor navigation through the materials; poor cellular connections, etc.).

Communicating and Interacting with People

Interaction can have little structure (messaging) or be highly structured, for reaching a goal as in collaborative and problem based learning. In both cases the new technology has much to offer. In the case of highly structured interaction, pedagogical models come into play in an important way. Activity theory, theories of adult informal learning, lifelong learning and etc. are at the basis of lots of experiments using mobile devices.

Let us start with the simplest interactions. Although simple learning-related applications may benefit from the messaging capabilities of mobile systems, only relatively few different educational bodies made experiments in this area.

At Kingston University (UK) an experiment was undertaken to research the effectiveness of a two-way SMS campaign in the university environment (Stone et al. 02a, b). The team has developed a system that sends SMS to students registered to the service. The content of messages is about their schedule, changes in it, examinations dates and places, student's marks and etc. After registering the students were automatically separated in 5 different groups. One group was receiving announcements via e-mail, other 3 groups via SMS (but different interaction was necessary in every group) and the last – via web. The conclusions of the experiment were that the students in certain scenarios where a certain type of response is required preferred SMS as a medium to e-mail or web-based announces. They feel the data is more personal and they like this. SMS could be efficiently used in education (m-learning) as a complementary media. As the technology improves (i.e. EMS and MMS, potential more user-friendly interface) the potential increases too.

At the University of Helsinki the *LIVE (Learning In Virtual Environment)* experiments, made with SMS system and with WAP phones, were very positive (Seppälä 02). The project went on by introducing digital imaging and sharing photos between the participants (teachers). The conclusions were that it is very possible that the introduction of MMS and the other 3G services in the large scene will lead to more and more possibilities for m-learning.

Another project (Garner et al. 02) on evaluation of a Short Messaging System (SMS) to support undergraduate students was done at Sheffield Hallam University. The experiment was with 67 undergraduate psychology students. The implemented system was for managing learning activities (to guide, prompt and support the students in their learning) rather than for learning. The findings were overwhelmingly positive, with students perceiving the system to be 'immediate, convenient and personal'.

Positive results were underlined and after the outcomes from a survey in Norway - almost 100% of the students in that University have cell phones and SMS system would be widely accepted (Divitini et al. 02). Once again an SMS system was considered to be used to spread information about lectures and classes, corrections in the schedule and etc. In certain cases students find it more convenient than e-mail or WWW as the information reaches them in real time.

Let us now consider cases of more structured interaction.

One of the biggest initiatives in the m-learning domain is the one of University of Birmingham – the *HandLeR* project (<http://www.eee.bham.ac.uk/handler/default.asp>). The project tries to understand in depth the process of learning in different contexts and to explore the lifelong learning. The stress is on communication and on human-centered systems design. The main concepts they investigate are concept mapping and knowledge sharing, lifelong learning, wearable learning technologies and conversation between mobile learners.

Similar in some concepts to *HandLeR* is the project undertaken at the Tampere University of Technology, Finland (Ketamo 02a) where PDAs are used for lifelong learning (mathematical education) of children. The study-content is presented in the form of a game (again the idea of human-centered education is explored) where the pupils can communicate and help each others and the electronic device is used to measure the average students' knowledge level and to adopt the speed of presenting new material to the learners'.

To support "Problem-Based" Learning was the aim of *KNOWMOBILE* project in Norway (Smørðal et al. 02) where PDAs and smart-phones were used for experiment in medical education of students from the School of Medicine at University of Oslo. The students were put in different environment and were given different devices (some of the students were living together and were having PDAs with possibility to connect to each other; another group were able to connect between each other via Internet but were working in separate location, and so on). After few weeks of experiment the team found out that the students are using the devices mainly to read information from the digital medical handbook (not to retrieve it via Internet as it was expected) and as communication device (to

discuss problems with colleagues but mainly for sending SMS messages and to organize social events after hours). The research) found that the reason for this was that even the medical students were eager to test the PDAs and investigate how they can be useful in learning they still had some technical difficulties. With proper guidelines and education the students could make it better so these problems are easy to overcome. They concluded that the PDAs should not be regarded as Personal Digital Assistants, but rather as gateways in complicated webs of interdependent technical and social networks.

Research on new forms/tools for collaboration is been going on in different institutions, schools and Universities. In few different projects people are experimenting on the collaborative conceptual mapping and notes-taking systems (Ketamo 02b; Milrad et al. 02). An example of such collaborative work is a project that took place at MIT (Klopfer et al. 02). The team uses PDAs to simulate the real environment (in the form of map) and to use simulation for a game, played by kids. They use PDAs equipped with GPS extensions. The idea is that the virtual world simulated on the PDA (which has the same geographical characteristics as real world) is “polluted”. Kids have to take “virtual” probes from the water and/or air in the polluted area or surroundings, analyze the results, interview people and read information about similar situations and finally find out how to sublimate the environment. During the game they collaborate by doing different probes and analysis and giving the results (reports) to their classmates or leaving them (probes and reports) in a certain place in the area (map), where other kids can find and use them. The kids have to collaborate because they are forced by time limitations.

Advanced wireless technologies (IEEE 802.11, Bluetooth, and GPRS) are used in a project for development of ad-hoc classroom and *eSchoolbag* system at the Aletheia University in Taiwan (Chang et al. 02). The so called “Paperless education” is being observed together with the acceptance from the students (the term “paperless education” and research on the topic is made also in (<http://www.paperlessclassroom.org/>)). The traditional classroom was replaced by the new developed electronic tools (electronic blackboard, rubber, color chalk and so on). Pupils were strongly encouraged to communicate and to learn together (in groups).

Applications for recording the data and taking notes had been developed for Palms and the pedagogical effect of them is analyzed (Aleahmad et al. 02; Slotta et al. 02).

Again in Taiwan (Liu et al. 02) students were equipped with network-connected PDAs and their achievements were shown on a whiteboard. The results from the pedagogical point of view were again very positive (as the students were very shy they preferred to keep quiet and the teacher could not find out the real level of their knowledge). Compared with traditional classrooms virtual environment and technology motivate more participation and collaborative dynamics between instructor and learners.

Conclusions

We have been trying to catalogue research on m-learning in three main areas: infrastructure, content and communication/collaboration. We shall here conclude first by providing some guidelines for m-learning applications, and then by summarizing the direction in which we believe valuable contributions are expected.

The nature of mobile devices, with their small screens and poor input capabilities leads to the assumption that they can not replace the standard desktop computers or laptops. But the same properties can make them efficient in learning domain. We report here some guidelines that can be found in (Steinberger 02, Figg et al. 02):

- Modules should be short, and last no more than 5-10 minutes. Users should be able to use their small fragments of waiting or idle time for learning, by reading small pieces of data, doing quizzes or using forums or chat.
- Simple, funny and added value functionality. The computational power and other properties of mobile devices make it difficult in most cases to use complex and multimedial content, although devices of the same size are used for entertainment with great commercial success. It should be possible to use an m-learning system without reading a user manual, and the experience of studying with the help of such devices should be interesting and engaging.
- Area/Domain specific content, delivered just in time/place. The mobility should bring the ability to guideline and support students and teachers in new learning situations when and where it is necessary. The dependency of the content can be relative to location context (i.e. the system knows the location where the learner resides and adjusts to it), temporal context (i.e. the system is aware of time dependent data), behavioral context (i.e. the system monitors the activities performed by the learner and responds to them adjusting its behavior) and interest specific context (i.e. the system modifies its behavior according to the user’s preferences).

As far as future directions are concerned, we think the main research topics could be the following:

- Pedagogical research is immediate and topical. Different learning approaches involving mobile devices should be considered and observed, to find which the most effective ones are given the conditions in which m-learning happens.

- The lack of convenient input tools pushes the research in exploration of new forms of user interfaces – for example sound or mobile scanning tools as input/output.
 - The small screens of the existing mobile devices give many research opportunities. Digital materials, used in e-learning should be at least partially reused, but a specific adaptation is required for them to serve m-learning needs. The best way to do the adaptation would be, of course, automatic customization/conversion. In general sense research in the area of device independent presentation of data serves also other domains, but an investigation is needed to find out how which the special requirement of m-learning are.
 - Related to e-learning are the services that students and teacher need, and that are typically provided by a Learning Management Systems. Providing such services via mobile devices is an applied research direction.
 - E-learning always depends on the connectivity of the end user. With the mobile devices there are periods of poor connectivity or no connectivity at all. M-learning could therefore be delivered in three different ways: “pure connection”, “pure mobility” and mixture of the previous two. “Pure connection” is when the mobile device is always connected to Internet (through WAP, GPRS, UMTS, Bluetooth, etc.). “Pure mobility” is when no connection is available and so all the data the applications need should be uploaded on the device and used offline. The first option gives strong impact on context-dependent applications, while the second approach needs research on data management.
 - Adaptation to the surrounding context in a mobile environment is also a very interesting and promising area.
- Finally, we note that whenever a new technology comes, it takes a while until its real potential is deployed, because we continue thinking according to old paradigms. We probably have not yet found the new paradigm for fully deploy e-learning, and yet another variation comes. It is up to our ingenuity to free ourselves from the “old thinking” and unleash the power of our fantasy to allow a new revolution to happen.

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