Towards a multi-vendor Mobile Learning Management System

Luigi Colazzo*, Andrea Molinari*, Marco Ronchetti+, Anna Trifonova+
** University of Trento – Department of Computer and Management Sciences - Via Inama 5, 38100 Trento Italy – Tel. +39 0461882144/2344 Fax +39 0461882124 E.mail colazzo@cs.unitn.it, amolinar@cs.unitn.it*
+ University of Trento – Department of Information and Communication Technology-38050 Povo (Trento) – Italy Tel. +39-0461882033- Marco.ronchetti@dit.unitn.it, Anna.Trifonova@dit.unitn.it

Abstract

The paper presents Porta-bile, a project under development in our University that intends to investigate the use of mobile computing technologies to support the learning processes in an educational context. The project focuses on the technological aspects of mobile learning, and on their integration with e-Learning systems, and more generally, with the information systems of the academic institutions. The project has its foundations in the availability of significant experience on e-learning real processes, and on the availability of the source code of an e-learning system developed in previous projects at the University of Trento and presently in production at the Economics school, and of the newer platform for the whole University of Trento that gathers the experience obtained in the past.

1. Introduction

In this paper we will present Porta-bile, a portal for mobile learning that is under development at our University. The main goal of the project is to experiment m-learning technologies in real learning processes taking place at a University. The use of ICTs for learning has been studied in various ways, but in the recent years quick advance of mobile technologies a new term has appeared – mobile learning. Mobile learning is a field which combines two very promising areas – mobile computing and e-learning. Mobile learning is intended as any form of learning and teaching that use mobile devices (like cellular phones, Personal digital assistants (PDA), smart-phones, tablet PC etc.) in a mobile environment. On the other side of mobile learning, we have e-learning, i.e., every educational process assisted by computers through the use of networks, and Internet in particular. M-learning is often considered as the future of learning, or as an integral part of any other form of educational process in the future. A mobile learning educational process can be considered as any learning and teaching activity that is possible through mobile tools or in settings where mobile equipment is available. In the first part of this paper, we shall briefly overview the state of research in the m-learning field. In fact, ass m-learning is quite a new domain, there is a lot of work and research that is presently going on. People are trying to understand:

- Which learning models can help obtaining better learning processes when communication is mediated by mobile devices, and how the student mobility affects her/his learning process.
- How it is possible to evaluate efficiency and effectiveness of learning processes based upon mobile technologies, given the physical limitation of mobile devices.
- Which services are useful for mobile devices, and which is the enabling technology that can affect the wide diffusion of mobile learning.

In the second part of the paper we shall discuss our approach to the problem: we intend to develop methodologies and tools for the design, the analysis and the prototyping of services for mobile computing. The coupling of advanced technologies, like the ones involved in mobile computing, with learning and assessment models represents an advanced point of research. We will propose a system that will integrate a traditional Learning management system with extensions that allow to face with infomobility, thus allowing users of a LMS to interact with the other actors through the use of mobile devices. This integration will be realized with web services technology, in order to be free from platform, operating systems and development framework constraints. The objective will be pursued through:

- Adoption of a well tested e-learning platform adapted to the usage of mobile devices
- Implementation of mobile computing services by using widespread mobile devices, on the client side, and web services on the server side.
- Study of learning models linked to mobile technologies, in order to understand in which way the use of limited devices impact the learning processes
- Design and development of Learning Objects suited to mobile learning, together with services for evaluating their effectiveness
- Experimentation of prototypes built in real learning processes

Another interesting aspect of the project is the experimentation of the integration between the two most used development frameworks for web application available on the market today, i.e., SUN J2EE and Microsoft .NET. The core of the Learning management system is in fact built on J2EE and java-related technologies, while the mobile extensions will be built on .NET framework. The interaction between the two will be granted once again by web services technology. We want to deeply test the most branded advantage of the web services technology, i.e. interoperability between platforms.

In fig.1 the system is presented: E-Leaf is the Learning management system currently under development in our University, and it is built in J2EE. It exposed to the world a set of interfaces that allows external modules to interface with it in different ways, one of which is through web services. The mobile extensions, on the contrary, are being constructed in .NET environment, and will interact with the core LMS system using web services. Moreover, the interaction between mobile devices and mobile extension will be once again guaranteed through web services.

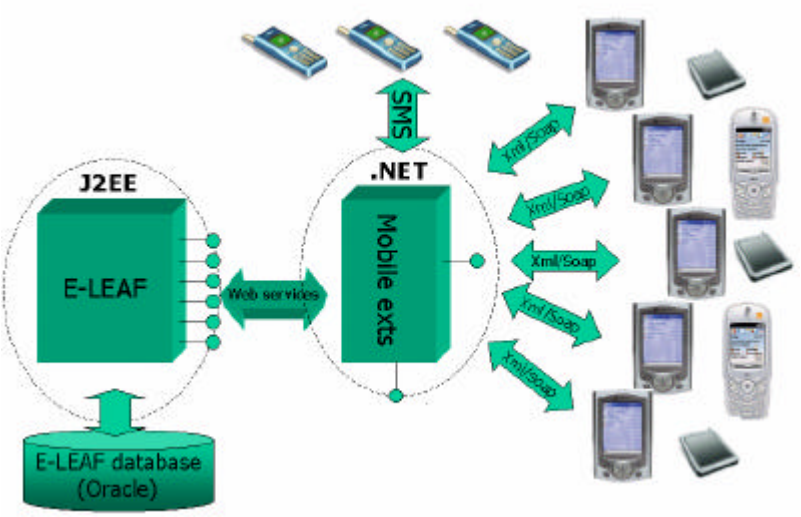

Fig.1 The architecture of the mobile portal

2. The mobile learning state-of-the-art

The current state-of-the-art in mobile learning research is quite heavily conditioned by the devices available on the market. Different devices that exist and all the devices that are coming up on the market, with their limitations and advancements, provoke different ideas for applying them on learning, thus any device can mean different ways to "m-learn". Among the open problems, some are relative to the pedagogical use of mobile devices. Since the m-learning term appeared for the first time, some research has been done to investigate the cognitive and pedagogical aspects. Investigation had been done also on how useful mobile computing devices could be for reading or for workplace activities [1], on the basis of studying activity theory. Some authors [2] try to give directions to application designers for the areas, where the mobile devices should be most useful. Others [3] are trying to achieve conclusions by analyzing the theories of adult informal learning. In a few papers some interesting positive sides of using new technologies are underlined i.e. the participants are excited and want to try "new" things. Some findings show that introducing new forms of teaching (even if this means just using a standard tool for drawing on a PDA) make students spend more time in working on that subject, comparing to the other subjects.[4] The evolution and the analyses of m-learning projects until now show many positive results. On the other hand there are some doubts if this excitement is, or is not, a temporary side effect. Most of the researchers think ([5][6]) that PDAs and other mobile devices should be seen more like extension, rather than replace the existing learning tools. Moreover not all kinds of learning content and/or learning activities are appropriate for mobile devices [7].

A number of m-learning projects focuses on the theme of how to apply e-elarning techniques on mobile platforms. An m-learning project concentrated on the testing of the use of WAP technology in higher education is the UniWap project ([8][9][10][11]). The team tries to explore the process of creating an operating environment for studying and teaching through smartphones and WAP phones. One phase of the project was to create some working prototypes (courses modules) and to investigate the problems and the value of such courses. 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 [12],[13]. The great potential is encountered from the cognitive and pedagogical point of view, but as the development is quite trivial (Macromedia Flash).

"From E-learning to M-Learning" [14] 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 their tries of finding the best way to apply mobile devices in education people are experimenting with different fields and one of them is language learning. Another field of research regards language learning. At Stanford Learning Lab [14] an exploration of mobile 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.

One of the most straightforward application of the usage of mobile devices as educational supporting tool is messaging. Again 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 0, 0. The team has developed a system that sends SMS to students, registered to the service, about their schedule, changes in it, examinations dates and places, student's marks and etc. 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. 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. For this reason, as explained in the next sections, we decided to include in our experimentation the management of SMS from teachers / administrative staff to students as one of the approaches to infomobility. Also at the University of Helsinki the *LIVE* (*Learning In Virtual Environment*) experiments, made with SMS system and with WAP phones, were very positive [17]. 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 [18] on evaluation of a Short Messaging System (SMS) to support undergraduate students was done at Sheffield Hallam University. The implemented system was again not for learning, but for managing learning activities (to guide, prompt and support the students in their 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 [19]. 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 this was comes always on time.These projects open two very important issues to be considered in doing further research in the mobile learning domain. The first one is that the current technology gives enough powerful instruments to support some new forms of auxiliary learning tools. They also show the enthusiasm of the students to accept such new technologies.

Tourist and museum guides are often considered as applications in mobile learning domain. They usually refer to newest technologies as location-discovery via GPRS, radio frequency or etc. Part of the already mentioned Ultralab project, is a project called *LAND* (*Location Activated Nomadic Discovery*). It explores the possibility to deliver media-rich context-aware information through mobile devices. The generation of 3D landscapes, based on actual position of the mobile device and on additional information could be a useful educational tool. For example students can go in a picnic in the mountain and then ask the system to generate the view of their current position but in the ice age.Tourist information could be considered as educational, so almost any tourist supporting system could be mentioned in the m-learning domain, but I think it is already differentiated as a separate field of research, so I will not talk about it more here. *The Electronic Guidebook* [20] is a project, in which mobile web content was specifically created for the Exploratorium museum (an interactive science museum) in San Francisco. Several recurring issues and themes emerged from the analyses such as users' sense of isolation and user attempts to make a seamless experience between real-place and virtual contexts. Teachers felt the mobile web content would be more useful as learning activities before and after museum visits. One of the biggest initiatives in the m-learning domain is the one of University of Birmingham – the *HandLeR* project [21]. 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. Similar in some concepts to *HandLeR* is the project undertaken at the Tampere University of Technology (Finland) [22], 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'.

In conclusion, the overall view on the existing research work and projects in the m-learning domain shows that it most probably applies best to processes, where specific knowledge should be retrieved/accessed in a certain moment, where discussions in distributed groups (i.e. brainstorming) appear, where data is collected or utilized "on the field", and where context-information is strongly related to the learning content. 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, if certain constraints are kept ([7][14][23][24]):

- Short, not more that 5-10 minutes long modules. The participants should be able to use their small fragments of waiting time (i.e. waiting for a meeting or while traveling in a train) for learning, like reading small pieces of data, doing quizzes or using forums or chat for finding answers to "on field" questions.

- Simple, funny and added value functionality. The computational power and other properties of mobile devices make it difficult to use complex and multimedial content. It should be possible to use an m-learning system without having to read a thick user manual and one should find it more interesting or necessary and useful (or at least equally) to study using this m-learning system in his/her 5 min. break than playing a game on the same device.
- 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). Of course a mix of the contextual dependencies is possible and likely.

3. Adapting a Learning management system to infomobility

In order to support the experimentation of any tool or technique of m-learning, a rather complex information system is necessary. Its role includes distributing didactic material, user identification and authorization, gathering of data relative to the user-system interaction, provisioning of mobile services etc. From this point of view, the Porta-bile project attempts to interconnect m-learning technologies with e-learning, and e-learning is in turn always more integrated in the information systems of academic institutions. E-learning systems, and Learning Management Systems (LMS) in particular, are nowadays a key element in the learning processes that take place at Universities, and they are widely investigated in literature [25],[26], [27], [28]. Several implementations are available on the market, like for instance LearningSpace™, WebCT™, Blackboard etc. [29]. They are in the middle of a transformation from simple support of on-line learning (like in the case of LMSs) into real information systems (Learning Information Systems - LIS). As such, they integrate many components of the wide spectrum of a formative action [30]. Our research program needs to integrate such systems with our project's specific mobile-computing requirements. This means that we have to focus mainly on two points: on the one hand we have all the administrative and back-office processes of a Faculty (e.g. exam registration, didactic design, theses management, bookkeeping of teachers activity, University marketing etc.). On the other hand, research attempts to focus on the technological evolution that brought to people mobility and mobile terminals (PDS, pocketPCs, cll phones, smart-phones, tabletPCs etc.) that are now present in every day's life. These tools are an interesting extension for a LIS, since they allow the different actors (students, teachers, administrative personnel etc.) to have a mobile platform that keeps them in touch wherever they are. The possible applications are therefore very many: we can for instance think at the possibility for a secretary to communicate with mobile-technology enabled students, or at possible mobile collaboration among teacher and students within a course framework (our research will explore this aspect).The idea of a LIS integrated with mobile technology is still unexplored, especially regarding the integration of the typical reporting/managing activity of an information systems with mobile devices.

The University of Trento has already built a Learning Management Systems (LMS) [31] that has been experimented for three years on all courses of some Faculties of the University of Trento. Following this experimentation, we are involved in renewing the system, and this renewal includes the redesign of the classes that build the system, in order to add functionalities related with mobility. In particular, due to the fact that the exchange of messages among different mobile devices and the system has a cost, it is necessary to include in the model some classes that provide the control and the accountancy of the offered services, that in turn will be defined based on the actors of the system (teachers, students, personal staff etc.). Following, the software that will distribute services on demand from and to mobile devices will be designed and produced. Typical services will be the access to the data commonly included in the database of the LIS, like the access from mobile equipments to calendars, the distribution of news related with the system (alert, results of exams, tax balance, etc.). Also the possibility of differentiate the configuration of the reminders both from mobile and desktop devices will be allowed, like for example notice of changes in the exams timetable, or expiration dates like taxes, exam enrollment etc.

The new LMS called e-Leaf strives to offer a modular infrastructure with a clean separation between data, business logic, presentation logic and actual presentation. It is built by using J2EE tools, and in particular it has an Enterprise Java Bean layer that abstracts the data from their actual database implementation and contains the business logic. On top of that, a layer based on the Struts framework contains the presentation logic, and exposes a set of JSP custom tags. Web designers are therefore offered something that might be thought as a conceptual extension of HTML, i.e. a set of tags that can be used and composed to build the actual presentation. The goal of such architecture is to allow "external" customization and maintenance of the system without knowing about programming, but maintaining a high level of freedom in the presentation choices. On the opposite side, it is possible to adapt the system to different data architectures without breaking the upper levels. For instance, we need to integrate data coming from an administrative system (that takes care of enrollment, taxes, student's career etc.) that is undergoing a transition to a new system. We strive to maintain an architecture that can be robust against such dramatic changes, and that can be adapted to other cases.

Two of the main modules of e-Leaf are identification and authorization: the first checks user's identity (against an LDAP system, with a fallback on to its proprietary database for users not registered in the LDAP but for which access has to be allowed), and the second maintains (conceptually) the matrix that associates users with resources,

allowing or denying access to the resources. This happens with a fine-grained access control mechanism that has been described elsewhere [32]. The other modules are relative to the main business of the LMS: they offer services to communities. Such services include chats, forums and shared spaces. Shared spaces, besides being used for uploading and downloading material, can be organized in several ways so as to offer the most useful views that the community administrator (typically the teacher) desires. An interface to data and services is provided through Web Service technology, so that a vendor-neutral door is opened to additional systems that may offer other functionalities.

4. The Mobile extensions

As seen in the previous section, E-Leaf has been built as a web services provider, and this is the assumption for the development of mobile extensions to the portal. As first activity, we decided on which devices to concentrate our development. This is a very important issue, as the market is continuously changing with new products emerging everyday. So, it is practically impossible to have a general mechanism for involving all possible devices currently available. We found the following devices useful for our experimentations:

- GSM/GPRS cellular phones
- PDA with Pocket PC/Windows CE
- Smart-phones
- UMTS telephones
- Tablet PCs

The platforms have been already found in their main components. These platforms will be the ones based with Symbian OS on one side (this means to involve the whole cellular phones market with the biggest world producers), and on the other side the platforms equipped with Windows CE, i.e. the PDAs that present points of contact with the Windows desktop environment in terms of applications and working environment. We will also experiment with the Palm OS, so that our experiment will cover a very large share of the market. The choice of producing learning applications for both the main PDAs environments is because we want to extend as much as possible the experiment, and most of all we want to create a self-assessment mechanism that must be generalized as much as possible with respect to technological platforms, due to the extreme volatility of the market. In the first step of the project, however, the choice made on some Microsoft™-dependent PDAs is related mainly on the consideration that most of the educational material is currently published in Microsoft™ software tools, especially PowerPoint and Word. In this sense, a device equipped with Microsoft™ operating systems will facilitate the interchange of educational material already available. However, the modular structure of e-Leaf and the approach followed in the building of web services based on XML and SOAP will provide a sufficient grade of extensibility of our mobile platform to other PDAs, like those that are equipped with Symbian OS. The test of the system will consist in some lessons conducted using Learning objects distributed using the LMS and used by students and teachers using PDAs, traditional viewers (like PowerPoint and Acrobat Reader) and other available mobile devices. Part of these educational materials will be available only through mobile devices: students will have to learn studying only on PDAs. In this way, different groups that have studied on different devices with different approaches will be available for our research: those who followed face-to-face lessons, those who studied on learning objects without following the lessons and those who studied on mobile devices. By creating a specific and calibrated set of tests, we want to verify the level of learning of the single groups, by analyzing the differences and the relative motivations. The results of these tests will be matched with the results of the self-evaluation tests distributed to the students, in order to verify thoroughly the level of learning reached by the students. The reactions of the students will be also analyzed, especially those related with problems in studying with a new but limited tool like a portable device. For this purpose, a forum on the web will be specifically activated, and some tutors will be available in order to help students with practical or technical problems.

As regarding the use of specific tools available with mobile technology, the most evident problem we faced in the design phase was the choice of the technology by which building the tools provided to the client in order to use our services. The current project provides ten different classes of services to mobile users, but in order to simplify the choice, we decided to concentrate initially on two different services for mobile devices:

- The management of SMSs sent by teachers to students or by administrative staff to teachers and students when particular events happen (meetings, reminder for expiration dates etc.)
- The consultation of a common agenda (we call it organizer) that will be available on the mobile device and will keep all the important dates for the actor (mainly students and teachers)

The first service is quite simple to build but not so easy to manage, if the LMS that operates behind the scenes does not have all the information needed. At the moment of writing, we have almost concluded this part of adaptation of the e-Leaf system currently available to the needs of managing SMSs messages. The main problem has been found in allowing the right person to send and receive SMSs, and in granting this permission inside correct boundaries, in terms of number of SMSs sendable by the user. The second service is under development and is more complicated, as it involves one of the most difficult task to manage inside a LMS, i.e., time management. We are currently building a system that allows students and teachers to connect with their mobile device and consult their agenda, dynamically built with all the events that could happen during a normal university activity. This implies a great effort of abstraction and integration between the LMS platform and the mobile devices. We have evaluated five different alternatives to build the interaction between the PDA (the platform chosen for the experimentation) and the central database. The problem is

related to the way the client (the PDA) interrogates the remote server module requesting the update of the events since last connection. These are the alternatives we evaluated and tested, from the simplest to the most complicated:

- Using the embedded browser of the PDA to navigate through the web pages that web users will see using the traditional browser available for desktop PCs. This is the simplest solution, both for the users and for the development team. Only a particular attention to screen adaptation is necessary, in order to concentrate the most important information on the left-uppermost part of the screen and to avoid the necessity of frequent scrolling. The web page will be created using device-specific tags and languages, like the .NET™ mobile toolkit, in order to navigate through the data available on the server. However, we decided not to follow this solution as the primary one, because of the necessity for the user to be constantly connected to the Internet to navigate through the organizer, thus requiring permanent connections (like WI-FI settings) or a significant expense for the students and the teachers when connected to the net using GPRS technology. In Italy this solution is very costly at the moment, and WI-FI technology with wireless LAN is still in its infancy. Other short-range connection solutions have been abandoned, as we want this service to be used outside the campus.
- Using a client database application, built specifically for mobile devices, that interrogates the server DB through the internet, synchronizing the data on the mobile device. This is a proprietary solution bounded to the back-end DB used and the availability of a Internet connection on the PDA, that requires also quite complicated settings from a end-user perspective. However, from our tests, this solution has the advantage of dramatically boosting performance thus reducing connection times.
- Synchronizing the PDA with the central database and the agenda of the user by using cradles and database synchronization: this solution will solve a lot of issues, but creates a problem in terms of cradle availability around the campus, and especially the problem of supporting different cradles for different models of PDA.
- Building a client/server application in which the client (on the PDA) uses traditional RPC/RMI mechanisms to invoke server methods in order to receive data. This has the advantage of requiring short-time connection to the central system, and could be personalized to the PDA device. The disadvantage of this solution is the proprietary mechanism of communication between server and client, and also the necessity of using particular TCP/IP – UDP ports that could complicate the management of security on the server side due to firewalls.
- Building a web application that request a web service through the use of XML/SOAP messages to the server. This is the best solution we found, as it provides the access in short time to the central database through the use of open technology like XML/SOAP, will use a port that is already opened for web access, and finally will guarantee the extension of the client part to other PDAs simply by creating the new client interface to the web service. We will therefore provide the agenda synchronization through a web service that will recognize the user, verify the state of his/her agenda, and will send an XML-formatted packet of data regarding last events in the system. The client side of the application, specific for the device, will format this data for the display: after that, the connection with the server will be closed and the navigation on the agenda will be completely off-line.

5. Conclusions

The project presented in this paper has the main objective of adapting the LMS currently used by the University of Trento to the needs of a portal for infomobility. Mobile learning is becoming a very interesting field due to the necessity of people to move also when involved in learning processes. In order to experiment mobile learning technologies in real-world settlements, it is necessary to have an e-learning management system: in other terms, the experimental conditions require that we must have:

- A software system for e-learning
- An academic institution that uses it and guarantees its correct operation
- A social environment accustomed to electronic communication in the process of learning / teaching

This system is currently in an advanced state of progress by the University of Trento, and we are adapting it to the mobile-computing needs required by the project using web services, XML and SOAP technologies. This will imply the creation of teacher-system-student interaction tools mainly based on SMS messages concerning the activities of these actors in the system. Moreover, the portal will provide an access point to the system's actors, in order to download the educational material and the self-evaluation tests produced according to the objectives of the project. Besides, different structures will be created to support the research activities, like forums usable via mobile technologies, mailing lists for the various users

As a second step, a specific agenda application for the mobile devices will be built, and it will use the web services technology to synchronize its data with the central database. We will conduct tests on the main platforms that currently equip the most widespread PDAs on the market. These platforms will be the ones based with Symbian OS, the Palm OS and Windows CE, so as to cover almost the whole cellular phones market and a very large share of the PDA market.

References

[1] Waycott J.: An Investigation into the Use of Mobile Computing Devices as Tools for Supporting Learning and Workplace Activities, 5th Human Centred Technology Postgraduate Workshop (HCT-2001), Brighton, UK, September 2001, available online at http://www.cogs.susx.ac.uk/lab/hct/hctw2001/papers/waycott.pdf

[2] Roibás A.C., Sánchez I.A.: Design scenarios for m-learning, Proceedings of the European Workshop on Mobile and Contextual Learning, (p. 53-56), Birmingham, UK, June 2002

[3] Rogers T.: Mobile Technologies for Informal Learning – a Theoretical Review of the Literature, Proceedings of the European Workshop on Mobile and Contextual Learning, (p. 19-20), Birmingham, UK, June 2002
[4] Dvorak J. D., Burchanan K.: Using Technology to Create and Enhance Collaborative Learning, Proc. of 14th World Conference on Educational Multimedia, Hypermedia and Telecommunications (ED-MEDIA 2002) , Denver, CO, USA, June 2002
[5] Kukulska-Hulme A.: Cognitive, Ergonomic and Affective Aspects of PDA Use for Learning, Proceedings of the European Workshop on Mobile and Contextual Learning, (p. 32-33), Birmingham, UK, June 2002
[6] Waycott J.,Scanlon E.,Jones A.:Evaluating the Use of PDAs as Learning and Workplace Tools: An Activity Theory Perspective, Proceedings of the European Workshop on Mobile and Contextual Learning, (p. 34-35), Birmingham, UK, June 2002
[7] Keegan D.: The future of learning: From eLearning to mLearning, http://learning.ericsson.net/leonardo/thebook/book.html
[8] Sariola J., Sampson J. P., Vuorinen R., Kynäslahti H.: Promoting mLearning by the UniWap Project Within Higher Education, Proc. of International Conference on Technology and Education (ICTE 2001), available online at http://www.icte.org/T01_Library/T01_254.pdf
[9] Sariola J.: What are the limits of academic teaching? - In search of the opportunities of mobile learning, TeleLearning 2001 Conference, Vancouver, Canada, available online at http://ok.helsinki.fi/tekstit/Article.rtf
[10] Sariola J.: What Are the Limits of Academic Teaching? – In Search of the Opportunities of Mobile Learning, available online at http://ok.helsinki.fi/pdf_tiedostot/mobileEN.pdf
[11] Seppälä P., Sariola J., Kynäslahti H.: Mobile Learning in Personnel Training of University Teachers, Proc. of IEEE International Workshop on Wireless and Mobile Technologies in Education (WMTE 2002) , (p. 23-30), Växjö, Sweden, August 2002
[12] Collett M., Stead G.: Meeting the Challenge: Producing M-Learning Materials for Young Adults with Numeracy and Literacy Needs, Proceedings of the European Workshop on Mobile and Contextual Learning, (p. 61-62), Birmingham, UK, June 2002
[13] Traxler J.: Evaluating m-learning, Proceedings of the European Workshop on Mobile and Contextual Learning, (p. 63-64), Birmingham, UK, June 2002
[14] Mobile Learning Explorations at the Stanford Learning Lab: A newsletter for Stanford academic community, Speaking of Computers, Issue 55, January 8, 2001, available on line at http://acomp.stanford.edu/acpubs/SOC/Back_Issues/SOC55/#3
[15] Stone A., Briggs J., Smith C.: SMS and Interactivity – Some Results from the Field, and its Implications on Effective Uses of Mobile Technologies in Education, Proc. of IEEE International Workshop on Wireless and Mobile Technologies in Education (WMTE 2002) , (p. 147-151), Växjö, Sweden, August 2002
[16] Stone A., Briggs J.: ITZ GD 2 TXT – How to Use SMS Effectively in M-Learning, Proceedings of the European Workshop on Mobile and Contextual Learning, (p. 11-14), Birmingham, UK, June 2002
[17] Seppälä P.: Mobile learning and Mobility in Teacher Training, Proc. of IEEE International Workshop on Wireless and Mobile Technologies in Education (WMTE 2002) , (p. 130-135), Växjö, Sweden, August 2002
[18] Garner I., Francis J., Wales K.: An Evaluation of the Implementation of a Short Messaging System (SMS) to Support Undergraduate Students, Proceedings of the European Workshop on Mobile and Contextual Learning, (p. 15-18), Birmingham, UK, June 2002
[19] Divitini M., Haugalokken O. K., Norevik P.: Improving communication through mobile technologies: Which possibilities?", Proc. of IEEE International Workshop on Wireless and Mobile Technologies in Education (WMTE 2002) , (p. 86-90), Växjö, Sweden, August 2002
[20] Lambdin D., Park P.: Helping Teachers COPE with Student Performance Data: An Interactive Assessments Database Tool, Proc. of 14th World Conference on Educational Multimedia, Hypermedia and Telecommunications (ED-MEDIA 2002) , Denver, CO, USA, June 2002
[21] HandLeR project web site: http://www.eee.bham.ac.uk/handler/default.asp
[22] Ketamo H.: mLearning for kindergarten's mathematics teaching, Proc. of IEEE International Workshop on Wireless and Mobile Technologies in Education (WMTE 2002) , (p. 167-170), Växjö, Sweden, August 2002
[23] Steinberger C.: Wireless meets Wireline e-Learning, Proc. of 14th World Conference on Educational Multimedia, Hypermedia and Telecommunications (ED-MEDIA 2002) , Denver, CO, USA, June 2002
[24] Figg C., Burston J.: PDA Strategies for Preservice Teacher Technology Training, Proc. of 14th World Conference on Educational Multimedia, Hypermedia and Telecommunications (ED-MEDIA 2002) , Denver, CO, USA, June 2002
[25] A'herran A., Integrating a course delivery platform with information, student management and administrative systems, in Proc. EDMedia 2001, Tampere, Finland, June 25-30 2001
[26] Hall B, Learning Management Systems. How to Chose the Right System for your Organisation, Brandon Hall, 2001
[27] McMahon M., Luca J, Courseware Management Tools and Customised Web Pages: Rationale, Comparisons and Evaluation, Proc. EDMedia 2001, Tampere, Finland, June 25-30 2001
[28] Hanna, D. E., Glowacki-Dudka, M. & Conceicao-Runlee, C. (2000). 147 Practical tips for teaching online groups: Essentials of Web-based education. Madison, WI: Atwood Publishing.
[29] Aggarwal, A. Web-based learning and teaching technologies: Opportunities and challenges. Hershey, PA: Idea Group 2000.
[30] Colazzo L., Molinari A. (2002) From Learning Management Systems To Learning Information Systems: One Possible Evolution Of E-Learning, in Proc. Communications, Internet and Information Technology (CIIT) Conference, St. Thomas, USA - November 18-20, 2002
[31] Colazzo L., Molinari A. (2002) An alternative system to deliver and manage on-line courses through the World Wide Web. In Proc. ED- Media 2002., Denver, USAm 24-29 june 2002. (vol. 1)
[32] Ronchetti, M. (2003) Achieving a low granularity access control in an e-learning management system. In Proc. ED- Media 2003., Honolulu, Hawaii, USA June 23-28, 2003