m-routes: An Ubiquitous Application for Off-line Evaluation of Educational Routes Using Mobile Devices

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Index terms: m-learning, ubiquitous computing, educational routes.

Abstract

In this paper, we introduce a novelty XML-Based m-learning author tool that, running on mobile devices like PDA's or Smartphones, allows us to find out the best way to teach a concept to a group of students. We call each different way of teaching a concept as an "educational route". The developed application can distribute different routes to every student and measure later the level of each students' progress checking their test marks statistics. Every route shows both text and images about any subject that will be used in order to explain a concept to the students. As a result, we can learn the best method to teach a concept to a group of students. Application runs off-line most of time and only is network/Internet connected whenever should be required. Initial performance was evaluated requesting user feed-back through informal interviews and a questionnaire about experience using mobiles devices as learning tools. A summarize evaluation of usability, user performance and behavior is presented and discussed respectively.

I. Introduction

The meaning of teaching can be summarized from different view points "a teacher cannot transmit knowledge to the students; a student must be able to relate the new subject to his previous cognitive structures" [1]. What teachers can do is to observe the assimilation of new concepts as an evolution of the levels of understanding [2]. There are two aspects to be considered: firstly, the cognitive growth in students can be described with a set of levels that enable teachers to more fully understand the complexity of their students thinking in relation to a topic/concept; the second aspect of the theory describes different teaching phases which may assist teachers in helping their students to grow from one cognitive level to the next one.

Teachers try to find the best way to avoid genetic, psychological, didactic and epistemological troubles associated to the learning task using different resources and methods, which could be named as "educational routes". These routes can be different, either in their approaches, or in the examples used in order to illustrate any concept. Also, they could share the same examples but given in a different order.

Moreover, the rapid development of new technologies have brought on many changes in activities, content distribution, strategies and attitudes in the field of on line education [3]. In this context, the spectacular development of Internet and the vertiginous rate in which mobile technologies and devices have been developed recently, provides us enough motivation for studying their impact on a natural area of education like e-learning [4] and "Mobile learning" abbreviated as m-learning [5] which indicates an ensemble of educational solutions which allow learning on mobile instruments through wireless transmission.

Thus, e-learning techniques oriented towards m-learning [6] are obviously a new frontier for education becoming more widespread each year because of it can be valuable when used as a part of a well-planned and properly supported education and training environment. Nonetheless, e-learning does not eliminate existing educational methods and pedagogical theories [7]. Rather, it complements them when they are used conveniently.

The educational research community has proposed authoring tools for taking tests in handheld devices. What is more, e-learning techniques can be used inside the classroom improving the collaborative learning using Tablet PC's [8], [9]. Although interaction is an absolute prerequisite for meaningful and constructivist learning, i.e., students who engage and interact are more likely to build the personal knowledge structures required for their learning [10], this can be complemented with tools which improve the students' self-learning capabilities.

Initially, in [11] authors introduced e-dap as an e-learning author tool implemented using only software under open source agreement in order to cover completely educational experience using ubiquitous computing for managing, distributing and capturing educational content. Next, in [12], [13] authors present an innovative

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application operating at the client side which allows students to take tests in their PDA's and Smartphones running application off line most of time.

In this paper, we introduce a novelty ubiquitous [14] XML-based application integrated in the previous architecture that, running on different mobile devices like Windows Mobile based PDA's or smartphones, allows teachers to distribute different education routes to different students and measure the level of each students' progress after learning a concept using a previously assigned route. This method allows us to store the tests in a portable and suitable format for different application clients. Both educational routes and tests have been developed using different Schema grammars supporting text as well as. Application runs off-line and only is network/Internet connected whenever should be required: in order to download new available versions of educational routes and tests and in order to upload the tests results to the main server.

The remainder of this paper is organized as follows: section II describes the concept of "educational routes" introduced in the paper, then section III introduces briefly Ubiquitous Computing. Next, section IV presents the application architecture with both server and client side respectively, including a description of the Route and Test interfaces. Section V deals with user feed-back after initial application use, including a summarized studio of usability and user preferences between PC and PDA versions of m-routes. To conclude, section VI presents main conclusions and work in progress.

II. Educational routes

As teachers, we could ask ourselves the next question: what is the meaning of teaching?. We could summarize that question from different points of view. From a constructivist view point, a teacher cannot transmit knowledge to the students, on the contrary, students must be able to relate any new subject to their previous cognitive structures through their activity [1].

What teachers can do is to observe the assimilation of new concepts as an evolution of the levels of understanding [2]. There are two aspects to be considered: the first aspect is a set of levels which describe the cognitive growth in students and enable teachers to more fully understand the complexity of their students thinking in relation to a topic/concept; the second aspect of the theory describes a set of teaching phases which may assist teachers in helping their students to grow from one cognitive level to the next one.

But, what exercises or experience are suitable in order to get that? The task of teaching a new mathematical concept presents several problems of different nature such as genetic, psychological, didactic and epistemological, due to the nature of the mathematical concept itself.

In synthesis, the theory of Van Hiele levels has been the center of attention of many researchers. Many doctoral theses, articles and investigation reports have been published to verify and to explore their approaches in relation to the learning, specially in the branch of geometry. Through their research, they have identified five levels of understanding spatial concepts through which children move sequentially on their way to geometric thinking [15]. There are four characteristics of these levels of thought:

- The Van Hiele levels of geometric reasoning are sequential. Students must pass through all prior levels to arrive at any specific level.
- These levels are not age-dependent in the way Piaget described development.
- Geometric experiences have the greatest influence on advancement through the levels.
- Instruction and language at a level higher than the level of the student may inhibit learning [16].

The Van Hiele model provides a description of the learning processes postulating the existence reasoning levels:

- Level 0: Pre-descriptive or pre-structural.
- Level 1: Visual recognition or one-structural.
- Level II: Analysis or multi-structural.
- Level III: Classification and relation or relational.
- Level IV: Formal deduction or extended abstraction. This is the highest level of thought in the Van Hiele hierarchy and it is well-known its detection difficulty. Its study only has a theoretical interest, that does not identify with skills of computational calculations or abilities of academic knowledge.

Teachers try to find the best way to avoid those obstacles using different resources and methods, which could be named as "educational routes". These routes can be different, either in their approaches, or in the examples used in order to illustrate the concept. Also, they could share the same examples but in a different order.

Based on the e-learning expectations, a teacher can design many educational routes in order to avoid the cognitive obstacles that he knows about the concept he is trying to explain. It would be very interesting

if teachers had an objective tool that allowed them to find out which of the proposed routes get the best results. The purpose is that students reach the level III (or over), in which it can be considered that all the elements guarantee the compression of a concept properly.

III. Ubiquitous computing

Ubiquitous computing is a concept introduced by Weiser [14] in 1991. This author wrote in his seminal article that computation would change in a manner that should be possible to use it in places where people usually spend most of their time like their own job places or even also their spaces of leisure. These technologies are characterized by being different from traditional desktop computers in the contexts in which they are used. Initially, intrinsic constraints of mobile devices were identified by technological limitations, e.g., poor computational resources or limited energy batteries. Fortunately, nowadays this situation has made headway with a high positive rate.

However, new items have just appeared to be evaluated like various aspects of human interaction with mobile devices which must be considered such as ergonomic constraints [17] and properties of ubiquitous access [18]. Consequently, they imply interaction dissimilar from how standard computers are usually operated. As a result, this interaction could be denoted like “natural” [19] in the meantime the voice, fingerprints or the glance are used.

The dialogue systems for the interaction with devices used in ubiquitous computation are included in a brunch in constant expansion. Within these, the systems applied to enterprise or educational surroundings are probably the less spread.

The use of mobile devices in educational surroundings can offer a degree of high yield when the interaction with other fixed or ubiquitous systems is performed off line, not being necessary to maintain busy the communication channel permanently. This allows us to optimize the concurrent accesses to the main server in which the information is stored, as well as to decrease the cost of connection, a fundamental issue to achieve success in the implementation as well as in the later use of the system. Short Message Service (SMS), Multimedia Messages (MMS) and ring tones download are probably the most extended services in mobile phone services but a new multimedia and business use of these devices is expected to be more and more usual.

IV. Application description

A. Architecture

Firstly, Extended Markup Language (XML) has been selected for the specification and development of both the educational routes and the self-evaluation tests. Then, a XML document is made up for the questions and answers stored in the application data base; concretely they travel from the main server to the client through an Internet connection. Both, document and required information for the correction are stored in the client, so it is not required to be network connected in order to take any test.

Secondly, the .Net Compact Framework Platform allows us to develop client applications for PC’s, PDA’s and Mobile phones, maintaining almost all of the written code unchanged. This allows us to create a more advanced user interface than if XHTML or WML [20], [21] were used, as well as to operate off line most of the running application time. Technology used for information exchange between server and the mobile device is based on Wi-Fi, GSM/GPRS or UMTS/HSDPA service. Then, two communication interfaces are developed in order to allow different types of services:

- **Service Level Interface**: it deals with the protocol used in the connection at low level.
- **Application Level Interface**: it contains the user interface controls and code for operating with the educational route as well as the stored tests so that teachers can obtain the skills of every student.

The storage of the item bank at the server side, as well as the results of the student’s evaluations have been developed using the relational database management system Firebird. This is the open source version (free of royalties) of the well-known data base manager Interbase. It fulfils the requirements of power, demanded scalability and open source license agreement for the application development and deployment. Furthermore, a .Net based Web service is developed to send the routes and the tests to the client and to receive the student’s answers. Figure 1 shows the proposed application architecture afterwards implemented.

The user interface is one of the most important issues to consider in the development of applications for mobile devices. Unlike desktop environments with multiple document interface applications, mobile devices have only one active task in a single window. Thus, user should be able to access easily to the different application functions, rather than struggling with the developed interface.

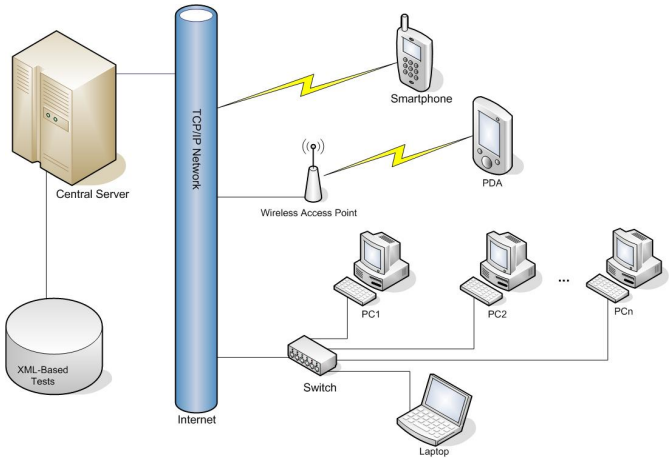

Fig. 1. System Architecture: Server side and client side for different kinds of devices: PC's, PDA's and Smartphones.

Fig. 2. PDA Interface: Application initial screen (left) and Main menu (right).

Unlike a standard PC application, the interface design considerations differ vastly. Potential users for this application could be students with different levels of computing skills. Consequently, the interface must be as simple and intuitive as possible. Application interface was designed to be used with a standard PDA pointer and the standard keys of any smartphone, i.e., requiring minimum number of user clicks to achieve a task. At client side, as depicted in figure 2, the application displays a customized menu offering different options, namely: (i) Route learning interface (Lección), (ii) Student test interface, (iii) Student test marks statistics (Resultados) and, (iv) Server synchronization (Descargas). Moreover, the developed interface does not need use of any text entry using device's keyboard, because of the reduced set of keys, i.e., entry of free text becomes in a very difficult task. The option for selecting tests displays a list of available tests stored inside the device.

B. Route interface

For the design of the routes screen, the smart size of this kind of devices must be considered. This screen shows the contents of the subject that a teacher try to introduce to the students, including both text and illustrations that make easier the learning process. As any route can be consulted several times by a student before taking a test, they must be stored in the device, so we selected XML as the format for the tests specification. Therefore, a schema grammar has been developed, allowing us to include both text and images and to distribute the information in different screens of data.

The grammar allows two columns, including text and images. Also application detects automatically the screen size, adapting the contents to the screen resolution, typically 480x640 or 240x320. In order to navigate between different screens, five buttons are displayed at the bottom: Next, Last, Previous, First and Exit. Figure 3 shows two of the screens designed for one of the routes of a probability course in the Computer Science Faculty. The route shows text and images in order to explain the concept of "Probability".

For every registered subject, each student is randomly assigned one of a set of available routes. The assignation process try to assign the same number of students to every route. Then, a configuration file

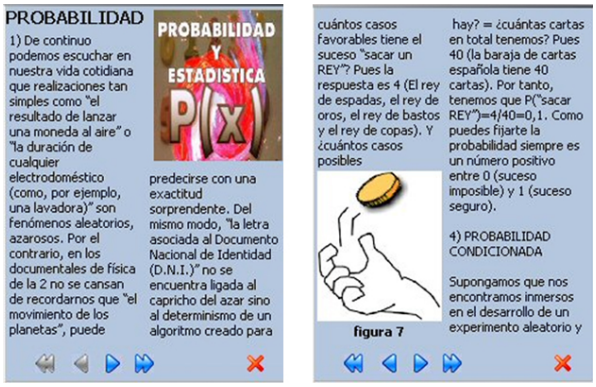

Fig. 3. Route interface running on a PDA with screen resolution of 240x320 screen PDA. Five buttons are used to navigate between screens.

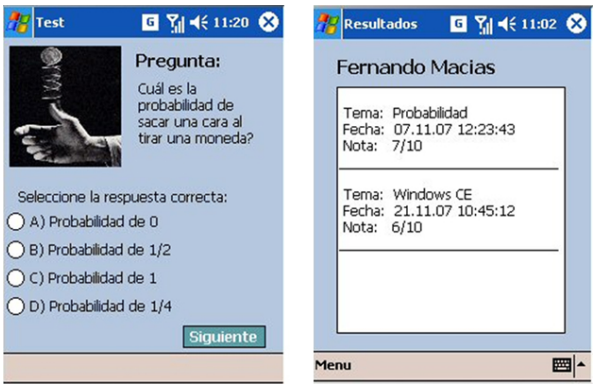

Fig. 4. PDA Interface: Test screen including the question, a descriptive image and four available answers (left). Results screen (right).

with the student's information is stored in the mobile device. During the synchronization process, only new versions of the previously assigned route and tests will be downloaded.

Later, when the test results of all the students are received in the main server, teachers will be able to study statistically which of the proposed routes provides better results. Since the results XML file also stores information about the student's accuracy on every question in the test, also it is possible to carry out a crossed study of what questions are not clear enough when they are explained with a particular route.

C. Test interface

When the test option is selected, a new form is displayed with three different zones (figure 4 left). The top-left zone of the screen shows the current question and its related image. In the middle, a list of radio buttons containing all the possible responses is displayed. The options are separated enough so that they can be selected with the stylus pen or even with the user's fingers. At the bottom, the *Next* button allows users to navigate between different questions. Whenever the student selects an answer, the system will check it and will re-evaluate his or her current ability. Then, information about the correctness of each response is stored as an attribute in an XML document.

After the student has answered the last question, the results screen is showed containing both the number of correct answers and the number of total questions answered. Moreover, the information is stored in a new XML document with the results of each test execution. Later, data will be uploaded to the main server for further analysis when the synchronization option is selected. The results option allows a student to review his or her progress and test marks statistics by means of a new screen showing the student's name, date and hour of test execution and the results marks statistics (figure 4 right).

When the test is finished, students can review all their answers as well as check the correctness of each one. The application displays a new screen showing the user's response and the correct response with a red font color. Therefore, the application can be used for both the teacher who later will be able to evaluate the most suitable educational route and for students, who can verify their level of knowledge on the subject studied with a particular route at this very moment. Four buttons: *Next*, *Last*, *Previous* and *First* are available

Fig. 5. PDA Interface: Review screen for two different answers with selected and correct response (red font) respectively.

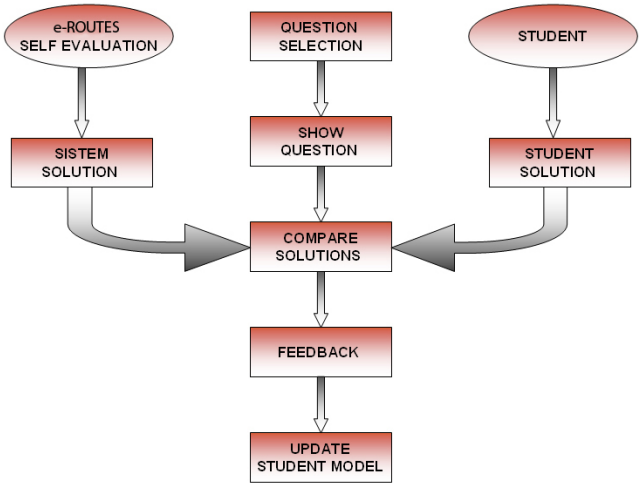

Fig. 6. Self-evaluation process in e-routes.

so that users navigate between the different questions of the test. The student can finish the review process by clicking on the exit button at any time.

Last, network connection is established only twice: firstly when new versions of tests are available and secondly, when the tests results previously stored after execution, must be sent to the central server. Most of the time, application operation is off line as tests and results are stored inside the handheld device (usually in a memory card expansion). At this point, we defend this configuration as a key point because of it allows us an important saving in connection economy costs to other technologies, like WML or XHTML, which require to be permanently connected.

D. Working flow

Self-evaluation is the main feed-back method of m-routes application. The application shows to the student his or her final estimation of ability on the screen, so it help them to strengthen the acquired knowledge. For the design of this functionality we have taken advantage of theories offered in [22] by the *Intelligent Tutorial Systems (ITS)* which are defined as a system that provides a hoisted individual education, with the objective of transmitting knowledge efficiently.

ITS supplies knowledge representation strategies to model the cognitive processes in the students and, as a result, ITS is able to provide knowledge to a rate and level of abstraction adapted to the student. Thus, considering the advantages of ITS, self evaluations are tests related to to the subject objectives that students can make. The system selects a question and compares its solution with the response selected by the student. Then a process of diagnosis takes place, based on the difference between the solutions.

Later, a suitable feedback is provided, and the system modifies the user model. This model stores which the student knows. Through this information, the system selects another question, according to the objectives (knowledge that the student must reach). When the test is finished, the student receives immediately information about obtained qualification (Fig. 6). This qualification will be registered and will be used

Fig. 7. PDA Interface: Subject selection screen (left) and Synchronization/Configuration screen (right).

to limit the access to later questions if the reached level is not enough. This motivates the student to take updated the knowledge of the matter.

Application can work with many different subjects each one with its own route and self-evaluation test, so a subject selection screen is showed at the beginning of the execution (Fig. 7 left). The synchronization menu option displays a new screen (Fig. 7 right) that allows students to specify the server URL for net connection, send the XML results file to the server and download new versions of both routes and tests.

V. Users feed-back

In this section we commented the use of the application described in the previous sections. In order to know the effects of the system on testing students performance and accuracy, an experiment was conducted. For this preliminary study, twenty students of a Web Programming course at the Miguel Hernández Computer Science Faculty participated actively. Most of them counted previously on the experience of using mobile devices like PDA's and Smartphone for earlier versions of the platform [12], [13], [23]. Overall, surveyed students responded very actively to the survey therefore, on the whole their reactions to this innovative learning system were well received.

Although authors did not perform a formative user study yet, user feed-back was requested trough informal interviewees and questionnaires and a summarize evaluation of usability, user performance and behavior was conducted. Students were asked about their experience with both PDA and PC version of e-routes application. The results of a questionnaire survey with ten different items are showed in table I. The questions of the survey were equal to ones used in [20] but we added some questions related to the option dealing with learning a route. Next, a set of identified challenges are listed.

Network limited availability; both the Wireless Network at Miguel Hernández University (UMH) Campus of Desamparados and GPRS/UMTS/HSDPA networks became the main user problem always dealing with network limits. In Spain, where this presented application is being deployed, many different telephony suppliers operate. Although GPRS availability is broad, generally UMTS/HSDPA connection is limited to open spaces only, so the wide band access technology could only take advantage of greater connection speed if the synchronization process is carried out outside the classrooms and buildings. Wireless network installation at UMH's campus has been recently finished, and Wi-Fi access is available almost in every place at the campus where the experiment was conducted.

Unlike XHTML or WML browser interaction, full-client program developed with .Net Compact Framework technology allowed the students to read the routes and to take the tests without permanent network interaction, therefore the problem was not too severe.

Almost all students thought that it was easier to concentrate their attention on reading a route and taking a test with their PDA's. In addition, almost all students thought that the application running on a handheld device provided more privacy and freedom than a standard PC inside a classroom or a laboratory when they were using the application.

The main drawback of the proposed framework was about the screen resolution of most of PDA's used in the experiment (240x320). More than a half of the students thought that the text font used in the PDA was more difficult to read than in e-routes version running on a standard PC or laptop with screen resolution over 1024x768 pixels. However, all of them showed a clear preference for taking tests with their PDA's as they could use it almost at any time from everywhere, despite of the smart screen size. We think this

TABLE I

RESULTS OF A QUESTIONNAIRE SURVEY WITH ALL 20 SUBJECTS

Item Description	PDA (%f)	PC (%f)
1. Which way is more convenient for you to take a test - with PDA in hand or sitting before a PC?	75.00 (15)	25.00 (15)
2. Which device do you like to use as an input tool - the stylus of the PDA or the keyboard and mouse of a PC?	80.00 (16)	20.00 (4)
3. Which kind of screen do you prefer when taking a test?	65.00 (13)	35.00 (7)
4. Which device's font do you think is easy for reading - PDA or PC?	30.00 (6)	70.00 (14)
5. Which platform can provide your privacy when taking a test - PDA or PC?	85.00 (17)	15.00 (3)
6. Which platform makes it easier to concentrate when taking a test - with PDA or with PC?	90.00 (18)	10.00 (2)
7. Generally speaking, which device do you prefer when taking a test - PDA or PC?	85.00 (17)	15.00 (3)
8. Which way is more convenient for you to read a route - with PDA in hand or sitting before a PC?	60.00 (12)	40.00 (8)
9. Which platform makes it easier to concentrate when reading a test - with PDA or with PC?	90.00 (18)	10.00 (2)
10. Generally speaking, which device do you prefer when reading a route - PDA or PC?	70.00 (14)	15.00 (6)

problem will be solved in a few months, when new generation of mobile devices with a resolution screen of 480x640 or even 640x800, becomes more and more usual. In the experiment, students used several HTC Touch Cruise PDA's with a screen resolution of 240x320 pixels. This device can access to Internet using not only Wi-Fi but also GPRS/UMTS/HSDPA.

VI. CONCLUSIONS AND WORK IN PROGRESS

E-learning environments designated to make easy long-distance learning are gaining popularity as new technologies make headway. Then, one contribution of this paper deals with passing one more step closer from e-learning techniques oriented towards m-learning which is obviously a new frontier for education.

The developed system allows students to use their handheld devices to learn a new concept and answer polls or fulfil tests almost at any time from anywhere. Moreover, teachers can measure both the level of each student's progress, checking their test marks statistics and find out which of the initially proposed routes provides the best results. A reliable and versatile application has been made that can be properly used in different scopes of education. In addition, a friendly and intuitive interface has been developed that makes easy its use and extends the group of potential users. For each subject, a student can learn his or her assigned route and take the self-evaluation test as many times as it was required to learn the concept. This allows them to know if the concepts have been assimilated.

Initial feed-back from interviewees and questionnaires leads to a conclusion that using PDA version of e-routes is at least as effective as a PC and more enjoyable. Although the results of this preliminary study show that most students preferred to use the PDA version of m-routes, conclusions must be viewed with caution, because this choice could be related to students' curiosity and novelty regarding with the use of handheld devices.

To conclude, the key advantages of our proposed author tool are: (i) Using ubiquitous computing has important implications for pedagogical issues because of students could access from heterogonous devices through GPRS/UMTS/HSDPA or Wi-Fi technology, without need of any changes at proposed architecture side, (ii) Design and usability aspects have verified how the use of handheld devices can provide new opportunities (and constraints) for learning and communicating, (iii) Evaluation suitable methodologies by allowing students to use their mobile devices to learn and answer polls or fulfil tests at any time from anywhere [24].

Las but not least, the client side application only connects to network/Internet whenever it is necessary, i.e., to download new versions of previously stored routes and tests if they are available, and to send the results back to the server in order to be statistically treated. As a result, the economy costs derived from using the system are as low as possible.

Our work in progress deals with using other mobile devices, like Java Mobile based phones with many technological limitations, that is poor computational resources, limited screen size and ergonomic constraints. Also, multimedia elements including audio or video, could be added to the routes and time constraints could be used both when a route is being read and when a test is being taken.

A more detailed study about usability, precision and ability estimation regarding with the use of m-routes is being performed. Also, different routes for several subjects, including statistics, object oriented programming and Web programming are being designed and XML coded in order to be evaluated using the proposed platform.

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