PCMAT, an Adaptive Learning Platform

Paulo Couto, Marta Fernandes, Constantino Martins, Luiz Faria
GECAD – Knowledge Engineering and Decision Support Group
Institute of Engineering – Polytechnic of Porto
Porto, Portugal
{pajco, mmaf, acm, lef}@isep.ipp.pt

ABSTRACT
This paper is about PCMAT, an adaptive learning platform for Mathematics in Basic Education schools. Based on a constructivist approach, PCMAT aims at verifying how techniques from adaptive hypermedia systems can improve e-learning based systems. To achieve this goal, PCMAT includes a Pedagogical Model that contains a set of adaptation rules that influence the student-platform interaction. PCMAT was subject to a preliminary testing with students aged between 12 and 14 years old on the subject of direct proportionality. The results from this preliminary test are quite promising as they seem to demonstrate the validity of our proposal.

Categories and Subject Descriptors
K.3.1 [**Computers and Education**]: Computer Uses in Education – *computer-assisted instruction (CAI)*.

General Terms
Measurement, Human Factors, Verification.

Keywords
PCMAT; adaptive learning platform; pedagogical model; adaptation rules.

1. INTRODUCTION
The main purpose of Educational Adaptive Systems (EAS) is to provide the student with contents and interaction options (navigation interface, etc.) in accordance with his/hers personal characteristics. Although numerous research and already developed systems have provided good results, more development, experimentation and implementation are still necessary to conclude about the adequate features and effectiveness of these systems [1].

The characteristics of each student reside in a predefined but updatable Student Model. This paper is about PCMAT, an adaptive learning platform, and its mechanisms to ensure the required adaptation and update of the Student Model. This paper is organized as follows: section II presents the PCMAT platform and the models that support it, the Metadata Editor – a web application specifically developed to allow the creation and

editing of the metadata associated to each learning object –, and the rules of adaptation inherent to the Pedagogical Model; section III gives notice of a preliminary test and the analysis of the obtained results; and section IV concludes the paper.

2. PCMAT's MODELS
PCMAT is largely based on the global architecture proposed by Benyon [2] and De Bra [3] for an Adaptive Hypermedia System (AHS). However, within PCMAT, the Interaction Model proposed by Benyon and De Bra was replaced by a Pedagogical Model that includes the mechanisms underlying the interaction with the platform as well as a set of rules of adaptation that controls the contents presented to the student and that updates the data in the Student Model. Hence PCMAT's structure comprises three main blocks: the Student Model; the Domain Model; and the Pedagogical Model.

2.1 The Student Model
The Student Model encompasses Domain Dependent Data (DDD) and Domain Independent Data (DID) [1], [4]. DDD consists of the knowledge that the system infers the student possesses on the domain, and it includes objectives, plan, complete description of the navigation, knowledge acquired, results of evaluations, etc. DID pertains to data concerning the student's profile. This data may be of two types: (1) generic – individual (name, email, address, etc.), demographic, academic background, skills, background knowledge, etc.; or (2) psychological – learning style, cognitive capacities, personality, etc.

PCMAT implements the Student Model by making use of knowledge and behavioral based techniques, namely stereotyping – this is, classifying students in groups and generalizing a student's characteristics to the group –, and by employing the overlay method – this is, relating the level of the student knowledge with the learning objectives/competences that he/she is supposed to reach. By employing the overlay method, it is assumed that "the student knowledge is a subset of the system knowledge" and that the "system does not allow representing the incorrect knowledge that the student acquired or might have acquired" [4].

The modeling of the student characteristics starts with the identification of the user subgroup, followed by the identification of key characteristics that identify the members of a user-subgroup, and the representation in hierarchical ordered stereotypes with inheritance.

A VARK strategies questionnaire and the Kolb learning styles matrix [5] were used to define the learning style of each student. DID is gathered from questionnaires along with the curriculum vitae and certificates of qualifications. Questionnaires and exams are used to capture the DDD.

2.2 The Domain Model

The Domain Model stands for a graph of concepts that provides a structure for the representation of the field of knowledge. This means that the Domain Model contains the concepts inherent to the domain, the rules that establish their hierarchical organization, plus all the possible connections between concepts. All this information, as well as the one pertaining to the Student Model, is stored in a database that allows its dynamic retrieval and update.

Likewise, each concept is materialized in one or more learning objects. Learning objects go by many names [6] but for the purpose of PCMAT a learning object (LO) is "any digital resource that can be reused to support learning" [7]. Associated to each LO is a metadata file containing:

— descriptive metadata – information pertaining to the LO creators, the LO identification, such as title, short description and keywords to help the search and retrieval actions;

— administrative metadata – such as when and how it was created, file type and other technical information, as well as copyright information; and

— educational metadata – as the typical age range of the intended user, difficulty and interactivity level, and the LO underlying concept(s), making it possible for the LO to be retrieved by the system if found suitable to a particular student's knowledge and learning style.

To make it possible for LOs creators to register the related metadata, a web application called Metadata Editor (ME) was developed. The records generated by the ME are LOM XML conforming instances, meaning that they can be used by any platform compliant with the IEEE LOM standard [8] [9].

The ME is a web application and distinguishes itself from some of its predecessors, like RELOAD[1] or Lompad[2], because it gives the domain administrator the means to define the metadata elements that he/she finds to be relevant or of mandatory filling, and to control the metadata inserted into some of these elements as, for example, the keywords. Keywords are an essential part of any LO retrieval action, thus leaving its choice to the sole understanding of the different creators of learning objects means, most of the times, that we will end up with a large number of synonyms. To avoid this, the ME allows for this type of elements to be defined as a controlled list from where keywords must be selected. Because the ME may not only be used by different domains as it actually makes it possible for a new domain to be created from its menu options, each domain must have its own set of keywords.

Another distinguishing feature of the ME is that it allocates each LO to a node of a 5 dimensions tree based on the metadata of the following elements of the LOM standard: interactivity type, learning resource type, interactivity level, semantic density and difficulty. This allocation allows for an easy way to discover the types of LOs that may be lacking in the domain by locating empty nodes in the tree, and plays a major role in the implementation of a specific set of rules of adaptation of the Pedagogical Model

[1] The *Reusable eLearning Object Authoring & Delivery* (RELOAD) tool is available at http://www.reload.ac.uk.

[2] The *Learning Object Metadata Editor* (Lompad) is available at http://helios.licef.ca:8080/LomPad/en/index.htm.

concerned with the selection of the content most suitable to the knowledge and learning style of the student [10].

2.3 The Pedagogical Model

The Pedagogical Model defines the rules of adaptation and the mechanisms of interaction between the student and the learning platform [4] [11]. This model was developed in cooperation with the teachers of mathematics involved in the project. Within the Pedagogical Model the knowledge about the student (represented in the Student Model) is used by the adaptation rules to define the learning path in the graph of concepts to be travelled by the student.

The rules of adaptation are based: (1) on the behavior exhibited by the student while accomplishing the activities proposed by the platform; (2) on the student's knowledge; and, (3) on the student's learning style. The curriculum is established by the teacher but is customized by the platform according to the student's knowledge, learning style, skills and learning path.

The developed rules of adaptation and the mechanisms of interaction enable PCMAT to [12]:

— validate the access of the student to a certain content or activity, being that each content and activity are related to one or more concepts;

— update the learning style and knowledge level attributed to the student;

— display contents according to the knowledge and learning style of the student;

— adjust the path travelled by the student within the graph of concepts to his/her knowledge and learning style;

— correct the learning style of a student based on his/her performance;

— control the structure of hyperlinks by hiding irrelevant links (*link hiding*), thus guiding the student to the relevant information and keeping him/her away from information or contents for which he/she may not be prepared.

Therefore, with PCMAT, the user requests an activity by clicking on a link in a Web page. Every page corresponds to a domain concept or a cluster of domain concepts. The system checks the suitability of the requested page for the current user. Updates to the Student Model are inferred from the interaction between the user and the application. The correct or wrong answers of the user allow the system to estimate the users knowledge level about the concepts related with the requested content.

3. PRELIMINARY TESTS AND RESULTS

For a period of three weeks, some preliminary tests were conducted with 61 students, aged between 12 and 14 years old, from three different classes, on the subject of direct proportionality. None of the students was familiarized with adaptive systems but the large majority (more than 85%) was experienced with using personal computers for browsing the internet, playing games or social networking.

The study was divided in three phases: (1) the students were divided in two groups, as balanced as possible in terms of gender, age, school grades and learning styles (a questionnaire was used for this purpose) – 30 students were placed in the experimental group that used PCMAT, and 31 students were placed in the

control group where they were taught without access to PCMAT, but with access to MOODLE (*Modular Object-Oriented Dynamic Learning Environment*) as it was common practice in the school; (2) questionnaires were used to collect the DID; (3) after the three week period, a paper exam, the same for all 61 students involved in the study, was carried out to assess their knowledge on direct proportionality.

The results obtained from the paper exam show an overall better performance from the students of the experimental group with a final average grade of 59,1% ($\sigma = 19,7$), while the control group obtained a final average grade of 44,2% ($\sigma = 21,8$). These differences are statistically significant having a p-value of 0,010.

Table 1. Paper test results

Quest.	Groups	Avg.	Rank	p-value
A1	Control	43,69	27,54	0,671
	Experimental	50,60	29,33	
A2	Control	57,69	23,85	0,036
	Experimental	79,00	32,53	
A3	Control	28,67	15,60	0,381
	Experimental	43,33	18,17	
A4	Control	15,53	12,23	0,005
	Experimental	57,39	20,97	
B1	Control	72,12	26,23	0,188
	Experimental	86,67	30,47	
B2	Control	31,92	26,85	0,410
	Experimental	42,67	29,93	
B3	Control	60,00	25,58	0,198
	Experimental	72,33	31,03	
B4	Control	35,58	23,35	0,020
	Experimental	63,33	32,97	
B5	Control	8,65	26,69	0,246
	Experimental	19,17	30,07	

Moreover, the grades obtained by each student on each of the eight questions of the paper exam (each question was related to a particular concept involved with direct proportionality) were also evaluated. The Mann-Whitney non-parametric test was used for statistical comparison. Analyzing the results displayed on table 1 it is visible that the experimental group scored better in every concept, but only the results obtained for concepts A2, A4 and B4 were statistically significant as they had a p-value of 0,036, 0,005 and 0,020 respectively.

4. CONCLUSION AND FUTURE WORK
In an attempt to show how techniques from Adaptive Hypermedia Systems (AHS) can improve e-learning based systems, a learning platform (PCMAT) was developed. This enabled the implementation of a newly developed Pedagogical Model with new sets of adaptation rules related to the selection of the most suitable content according to the student knowledge and learning style. The results obtained with the preliminary study are quite promising, and seem to validate our proposal, nonetheless, we are aware that further tests with larger samples are required to confirm the impact of the Pedagogical Model on the obtained results.

5. ACKNOWLEDGMENTS

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