An Adaptive Educational System For Higher Education

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1. EXECUTIVE SUMMARY

The main objective of an Adaptive System is to adequate its relation with the user (content presentation, navigation, interface, etc.) according to a predefined but updatable model of the user that reflects his objectives, preferences, knowledge and competences [Brusilovsky, 2001], [De Bra, 2004]. For Educational Adaptive Systems, the emphasis is placed on the student knowledge in the domain application and learning style, to allow him to reach the learning objectives proposed for his training [Chepegin, 2004]. In Educational AHS, the User Model (UM), or Student Model, has increased relevance: when the student reaches the objectives of the course, the system must be able to re-adapt, for example, to his knowledge [Brusilovsky, 2001].

Learning Styles are understood as something that intent to define models of how given person learns. Generally it is understood that each person has a Learning Style different and preferred with the objective of achieving better results. Some case studies have proposed that teachers should assess the learning styles of their students and adapt their classroom and methods to best fit each student's learning style [Kolb, 2005], [Martins, 2008]. The learning process must take into consideration the individual cognitive and emotional parts of the student. In summary each Student is unique so the Student personal progress must be monitored and teaching shoul not be not generalized and repetitive [Jonassen, 1991], [Martins, 2008].

The aim of this paper is to present an Educational Adaptive Hypermedia Tool based on Progressive Assessment.

1.1. Platform Development

Our platform application is based on AHA (Adaptive Hypermedia Architecture). AHA is a Web-based adaptive hypermedia system capable of performing adaptation based on the user's browsing actions [Wu, 1999].The learning platform developed has a constructivist approach, assessing the user knowledge and presenting contents and activities adapted to the characteristics and learning style of the student. Also, the platform allows students and teachers to autonomously create and consolidate knowledge, with permanent automatic feedback and support, through instructional methodologies and educational activities explored in a constructivist manner. The adaptation of the application is based on progressive self-assessment (exercises, tasks, etc.) undertook by the student that evolves in difficulty and topic. The scheme is set by the teacher but is individualized to each student’s level of knowledge, competences, abilities and learning path. The platform is also connected to tutorials that are contextually accessed by the students when they fail a progression step. All the data are store in the database or in XML files. The knowledge of the student is consolidated with permanent automatic feedback and support, through instructional methodologies and educational activities explored in a constructivist approach.

The first version of the framework was already implemented, tested and evaluated in learning processes in higher education [Martins, 2005], [Martins, 2008].

2. Introduction

The main objective of an Adaptive Systems is to adequate its relation with the user (content presentation, navigation, interface, etc.) according to a predefined but updatable model of the user that reflects his objectives, preferences, knowledge and competences [Brusilovsky, 1993], [De Bra, 2004].

For Educational Adaptive Systems, the emphasis is placed on the student knowledge in the application domain and learning style, to allow him to reach the learning objectives proposed in his training [Chepegin, 2004].

Constructivism is the dominant learning theory of the last decade and according to this theory, knowledge is actively constructed by the student in adaptive process. The application of the constructivist learning theory is more and more used and it suggests that the students do not simply keep the information in a static way, but look for blocks of old related knowledge to construct a new and more significant "learning" process [Martins, 2005], [Martins, 2008].

This paper is organized as follows. Section III provides a general approach to Adaptive Hypermedia Systems (AHS). The section IV defines Student Model and sections V introduce the Learning Styles concept. Platform Development and Some Results are presented in section VI and VII. Finally section VIII presents Conclusions.

3. Adaptive Hypermedia Systems

Adaptive Hypermedia (AH) is generally referred as a crossroad in the research of Hypermedia and User Modeling (UM) [Brusilovsky, 2001], [Brusilovsky, 1996], [De Bra, 2004]. An AHS builds a model of the objectives, preferences and knowledge of each user and uses it, dynamically, through the Domain Model and the Interaction Model, to adapt its contents, navigation and interface to the user needs.

De Bra in 2004 [Chepegin, 2004] indicates that these systems must present the functionality to change content presentation, links structure or links annotation.

The global architecture proposed by Benyon [Benyon, 1993] and De Bra [De Bra, 2004], indicates that AHS must have three essential parts: the User Model, Domain Model and Interaction Model.

Several architecture models already have been implemented with success, such as for example the [Wu, 1999]: Dexter Model; Amsterdam Hypermedia Model (AHM); Adaptive Hypermedia Application Model (AHAM) or Munich Reference Model.

In Educational Adaptive Hypermedia Systems, the emphasis is placed on students' knowledge in the domain application and learning style, in order to allow them to reach the learning objectives proposed in their training [Martins, 2008].

The application of the constructivist learning theory in AHS is increasingly popular. The learning process is more efficient when it is built in a base of a knowledge learnt previously and it will be still more useful if is actively implicated in the process of increasing the level of association with this knowledge [Martins, 2005], [Martins, 2008].

4. Student Model

The beginning of User Modeling (UM) is dated to 1978/1979 with the first work by Allen, Cohen, Perrault and Rich Kobsa, 1993]. In the following 10 years, numerous applications or systems were developed to store different types of user information to allow distinct adaptation models. Morik, Kobsa, Wahlster and McTear present an extensive survey of these systems [Kobsa, 1993]. In these initial systems, user modeling was embedded and there was not a clear distinction from other components of the system [Kobsa, 1993].

In middle 80's, this separation was made, but no efforts were carried out to allow the reuse of information between adaptive systems [Martins, 2008]. In 1990, Kobsa was the first author to use the term "User Modeling Shell System". Since then, different systems have been developed with the ability to reuse User Models [Kobsa, 1993].

In generic AHS, the User Model allows changing several aspects of the system, in reply to certain characteristics (given or inferred) of the user [Brusilovsky, 2001]. These characteristics represent the knowledge and preferences that the system assumes that the user (individual, group of users or no human user) has.

In Educational AHS, the UM (or Student Model) has increased relevance: when the student reaches the objectives of the course, the system must be able to re-adapt, for example, to his knowledge [Brusilovsky, 2001].

A Student Model (SM) includes the Domain Dependent Data (DDD) and the Domain Independent Data (DID). The components of the Domain Dependent Data correspond to the Domain Model with three-level functionality: Task level; Logical Level and Physical Level.

The Domain Independent Data (DID) are composed of two elements: the Psychological Model and the Generic Model of the Student Profile, with an explicit representation [Kobsa, 1993].

5. Learning Styles

The key of constructivism theory is that student must be actively involved in the learning process. It is important that teachers understands that the construction of knowledge acquisition occurs from knowledge that student already possesses and differs from Student to Student. The role of the Teachers is now to be a guide of the student [Jonassen, 1991].

The emphasis in student individual differences is also important in a context to recognize, design and support students activities (tasks). In constructivism learning theory, Students have different learning Styles. Also, the capacity of adaptation in different social contexts and the constructive social aspect of knowledge must be taken into consideration [Jonassen, 1991].

Generally, Learning Styles are understood as something that intent to define models of how a person learns. Generally it is understood that each person has a Learning Style different and preferred with the objective of achieving better results. Some case studies have proposed that teachers should assess the learning styles of their students and adapt their classroom methods to best fit each student's learning style [Kolb, 2005], [Stash, 2005].

VARK Strategies is a questionnaire that provides users with a profile of their learning preferences. These preferences are about the ways that they want to access and select information. These models/strategies describe three basic learning styles: Visual learning (learn by seeing); Auditory learning (learn by hearing) and Kinesthetic or practical learning (learn by doing).

Kolb Learning Styles Model which as a behavioral model, is a guide and not a strict set of rules, is based on the four stages of the learning cycle: Concrete Experience - (CE), Reflective Observation - (RO), Abstract Conceptualization - (AC) and Active Experimentation - (AE) [Kolb, 2005], [Stash, 2005].

From these levels the matrix was defined to allow the classification of the Student learning Styles (Table 1).

Table 1. Kolb Learning Styles matrix [Kolb, 2005].

	doing (Active Experimentation - AE)	Watching (Reflective Observation - RO)
feeling (Concrete Experience - CE)	accommodating (CE/AE)	Diverging (CE/RO)
thinking (Abstract Conceptualization – AC)	converging (AC/AE)	assimilating (AC/RO)

The Learning process must take into account the individual cognitive and emotional parts of the student. In summary each Student is unique and his personal progress must be adapted and not generalized and repetitive [Jonassen, 1991], [Martins, 2008].

6. Platform Development

The platform application developed is based on AHA! (Adaptive Hypermedia Architecture) [Wu, 1999]. AHA is a Web-based Adaptive Hypermedia system capable of performing adaptation that is based on the user's browsing actions. AHA! is an Open Source project built on Java Servlet technology that uses XML and XSLT and mySQL for database. AHA! provides some adaptation features such as for example adaptive content by conditionally including fragments, and adaptive navigation support by annotating links [Wu, 1999].

The User Model of AHA! consists of concepts with attributes. The User Model is stored in the mySQL database or in the form of XML files. The authors can influence the possible updates to the UM through the concept structure and the associated adaptation rules [De Bra, 2004], [Martins, 2005].

The AHA! Domain Model consists of a set of concepts, with associated attributes and adaptation rules. Most concepts are associated with pages [Martins, 2005].

AHA! doesn't provide any questionnaires to define student learning styles, but can provide mechanism for inferring the learner's preferences corresponding to an specific learning styles.

The Adaptation Model of AHA!, describes how to update the user model and how to generate the adaptation based on the User Model and the Domain Model. This Adaptation Model defines the adaptation rules.

5.1 Definition of our platform

The learning platform developed has a constructivist approach, assessing the user knowledge and presenting contents and activities adapted to the characteristics and learning style of the student.

Also, the platform allows the students and teachers to autonomously create and consolidate knowledge, with permanent automatic feedback and support, through instructional methodologies and educational activities explored in a constructivist manner.

The adaptation of the application is based on progressive self-assessment (exercises, tasks, etc.) (AHA! presents only Multiple-Choice Tests) solved by the student that evolve in difficulty and topic. The scheme is set by the teacher but is individualized to each student's level of knowledge, competences, abilities and learning path. The platform is also connected to tutorials that are contextually accessed by the students when they fail a progression step.

Also the project defines and evaluates the characteristic of the User Model to be used in the Student Model. For the definition of the student characteristics to be store the application takes into account the Domain Model and a constructivist approach.

All the data are store in the database or in XML files.

The knowledge of the student is consolidated with permanent automatic feedback and support, through instructional methodologies and educational activities explored in a constructivist approach. Thus it is possible with to create and validate of a reference framework that makes possible to adapt the use of learning objects in accordance to the constructivist analysis of the student and his performance. The usage of the user profile is very important to avoid generating questions, tasks, etc based on knowledge that has not yet been presented to the learner. The constructivist approach is also followed in the sense that the platform suggests some references to the student according with the response of the progressive self-assessment (exercises, tasks, etc.).

For the definition of the Adaptation Model, it uses the student characteristics in the User Model. With this knowledge, it is possible to define the concept graph by each user. This graph will be used in the Adaptation Model to "apply" on the Domain Model of the system. The route used in the graph is defined by the interaction with the student using an progressive assessment. Also the route is defined by the representation of the student knowledge defined by the Overlay Model and by the user characteristics store in the UM.

In order to evaluate the system one course in one Polytechnic school was used. The course chosen was PHP Language (Fig.1).

The student access the platform in a classroom adapted for this effects in two sessions per week (two hours each) with the teacher guidance and also more four hours per week from any local with access to Internet.

All the privacy aspect was considered in the application.

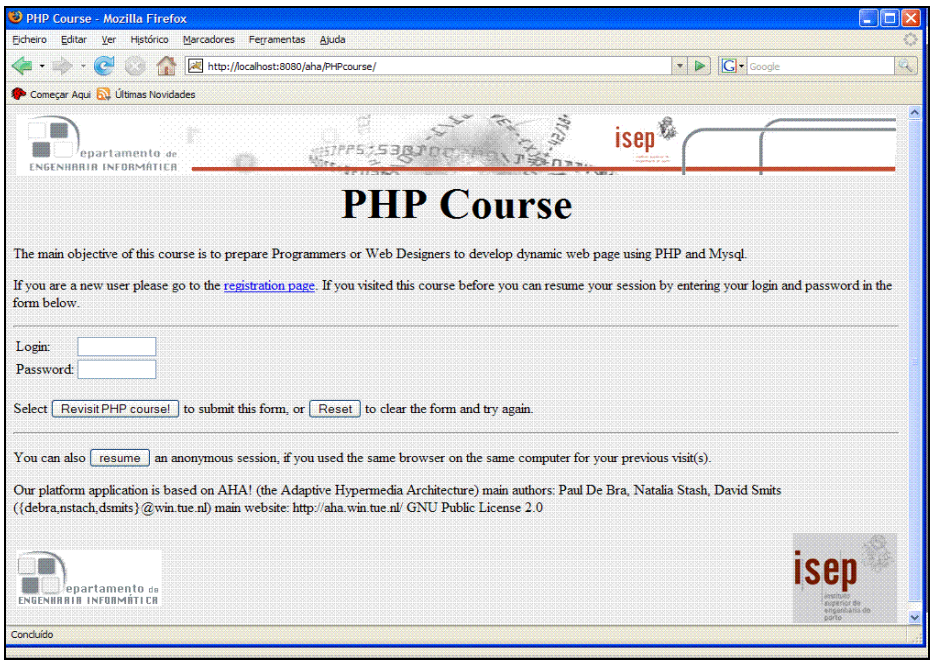

Fig. 1. Framework initial page.

5.2 Student Model Implementation

Two different types of techniques can be used to implement the Student Model: Knowledge and Behavioral based [Kobsa, 1993]. The Knowledge-Based adaptation typically results for data collected through questionnaires and studies of the user, with the purpose to produce a set of initial heuristics. The Behavioral adaptation results from the monitorization of the user during his activity.

The use of stereotypes classifies users in groups and generalizes student characteristics to that group [Martins, 2008]. The definition of the necessary characteristics for the classification in stereotypes must consider the granularity degree wanted.

The Behavioral adaptation can be implemented in two forms: the Overlay and the Perturbation methods [Martins, 2008]. These methods relate the level of the student knowledge with the learning objectives/competences that he intends to reach [Martins,2008].

The approach to build the User Model (UM) is the Stereotype Model with the Overlay Model for the knowledge representation of the student.

The representation of the stereotype is hierarchical. Stereotype for user groups with different knowledge have been use to adapt information, interface, scenario, goals and plans. The user stereotypes, or the establishment of typical characteristics groups, where each user fits, was applied in the definition of the User Model. The granularity degree wanted was taken into account, too. First, it identifies the user subgroup (using for example questionnaires and learning styles), then the identification of key characteristics (which one to identify the members of a user-subgroup) and finally the hierarchical representation of the stereotypes with inheritance.

The User plan is a sequence of user actions that achieve a certain goal. The System observes the user actions and try to infer all possible user plans. This goal is possible because the system possess a library of all possible user actions and the preconditions of those actions.

A large number of criteria can be established in the Stereotype definition depending on the adaptation goals.

The definition of the characteristics of the student will took in account the Domain Model and the constructivist approach of the application (Table 2).

Table 2. Characteristic used in the SM.

Model	Profile	Characteristics
Domain Independent Data	Generic Profile	Personal information
		Demographic data
		Academics background
		Qualifications
		Knowledge (background knowledge)
		Deficiencies: visual or others
		Application Domain
	Psychological profile	Learning style
		Cognitive capacities
		Traces of the personality
		Inheritance of characteristics
Domain Dependent Data		Objectives
		Planning / Plan
		Complete description of the navigation
		Knowledge acquired
		Results of evaluations
		A context model
		Aptitude
		Interests
		Deadline extend

The tools used to collect date are:

- Domain Independent Data:
  - Questionnaires, certificates and C.V.;
  - Learning Styles, questionnaires and Psychological exams;
- Domain Dependent Data:
  - Questionnaires and exams.

Concerning that and the objective of Domain Dependent Data, the user's aptitude and assessments result are monitored.

5.3 Domain and Adaptation Models Development

The Domain Model uses concept hierarchies and the related structure for the representation of the user knowledge level (quantitative value) (Fig. 2).

The Domain and Adaptation Model use the student characteristics from the User Model (UM). With these functions, it is possible to define the concept graph by each user to use in the Adaptation Model to "apply" on the Domain Model of the system. The route used in the graph is defined by:

- The interaction with the student using a progressive assessment;

- The student knowledge representation defined by the Overlay Model;
- The user characteristics in the UM.

The system adaptation (adaptation to content or links) to the user can cause user model updates as well.

The results of Domain and Adaptation Models achieve in:

- The development of the concept graph by each user to use in the Adaptation Model to "apply" on the Domain Model of the system;
- The Definition of the Adaptation Model using the characteristics of the student in the User Model.

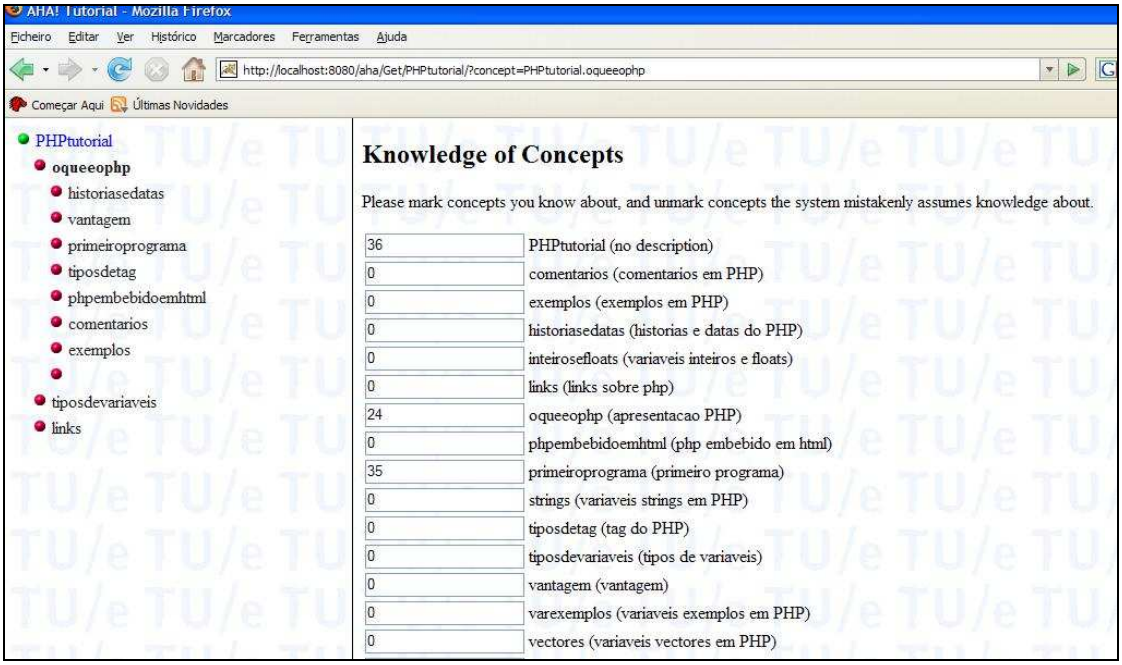

Fig. 2. Knowledge of Concepts.

5.4 Interaction Model

The Interaction Model represents and defines the interaction between the user and the application..

In the Interaction Model, the system offers the functionalities to change the content presentation, the structure of the links or the links annotation with the follow objectives for the student [De Bra, 2004]. The user is guided to the relevant information and kept away from the irrelevant information or pages that he still would not be able to understand (Fig. 3). The technique used is generally known by link adaptation (Hiding, disabling, removal, etc.). Also, the platform supplies contents (pages), additional or alternative information to ensure that the most relevant information is shown. The technique that is use for this task is generally known as content adaptation.

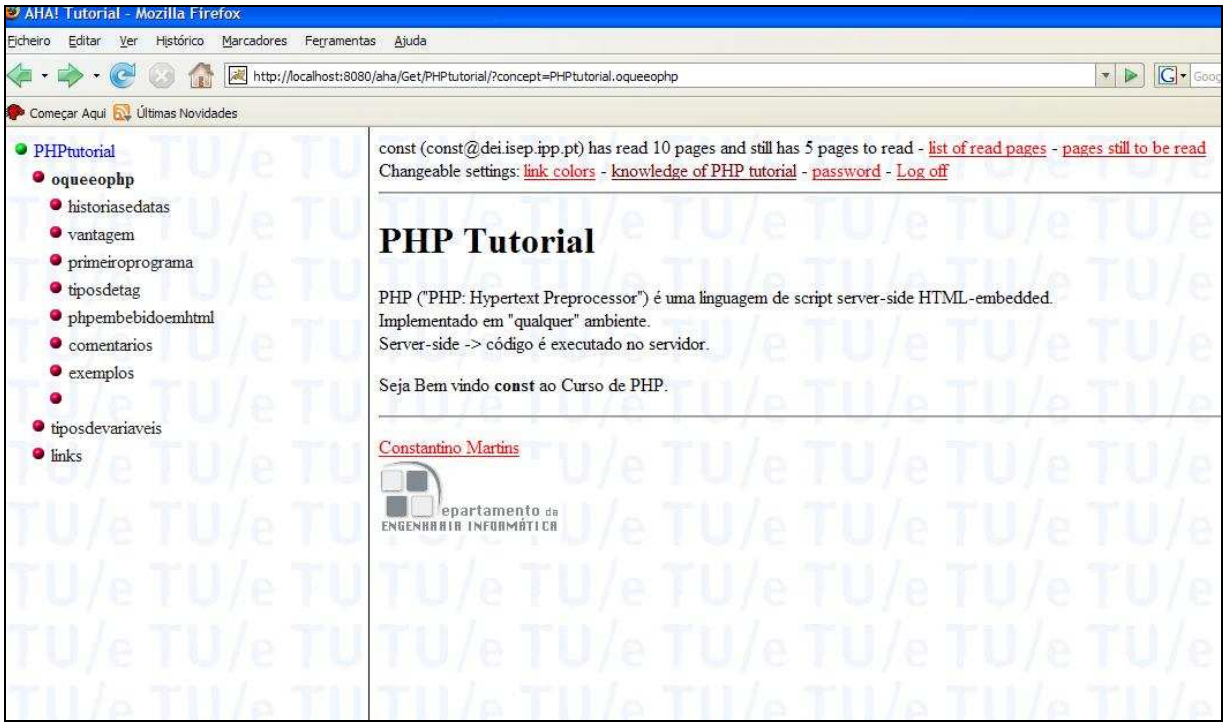

Fig. 3. Link Interaction.

The interaction model is able to use multimedia adaptation technologies to choose the type of the content more appropriated according to the profile of the student (for example, according with some user disability).

To improve content understanding by providing adaptive narration, the adaptation techniques using Natural Language Adaptation will be provide the next step of the platform development [Brusilovsky, 1996].

The constructivist approach is also present in the sense that suggestions of references and activities are provided to the student according to the response of the progressive self-assessment exercises, tasks, etc.

7. Some Results

The first version of the framework presented in previous section, has already been implemented, tested and evaluated in learning processes in higher education (Fig. 1). The collected evaluation data have showed a very high degree of interest and motivation from students and teachers alike, resulting from its use. Students also perceived this tool as very relevant for their learning, as a self-operating application to be integrated in a more global learning strategy that includes also tutoring (direct contact with the teacher) and per learning. Teachers agree with these definitions of the platform, as well [Martins, 2005].

Another result was the definition of new strategies and an architecture for the implementation of the Educational Adaptive Hypermedia platform.

The capacity of adaptation of this tools in relation with the different necessities and the diversity of the background of each student is necessary for higher effectiveness and efficiency of the learning process. The increased responsibility of the student in the education process is in accordance with the individualization and adaptability of learning process proposed. Thus it will be also possible to increase the responsibility of the student in his learning process.

The main result of the present development was the validation of a user reference model that will support new adaptive functionalities based on the use of learning objects to truly support a constructivist learning and cognitive path.

The definition of the characteristics of the student to be stored and the selection of the techniques of the Overlay Model and stereotype for the representation of the user knowledge's in the UM and the Adaptation Model were defined. The number and type of characteristics to use depend on the purpose of each system, but some relevance must be given to the cognitive part, learning styles and student knowledge [Martins, 2008].

At present, ours research of the Student Model and AHS, goes in the direction to make possible the reuse of each student model in different systems. The standards are becoming more and more relevant for this effect, allowing systems to communicate and to share data, components and structures, at syntax and semantic levels [Chepegin, 2004], even if most of them still only allow syntax integration [De Bra, 2004].

8. Conclusion

In the scientific area of User Modeling, numerous research and developed systems already seem to promise good results [Kules, 2000], but yet some experimentation and implementation are still necessary to conclude about the utility of the UM. That is, the experimentation and implementation of these systems are still very scarce to determine the utility of some of the referred applications.

In the educational AHS, emphasis is put on the student knowledge related with the domain application, in the sense of making the most effective adaptation and allowing the student to reach his objectives [Chepegin, 2004].

The analysis, application, implementation, integration and evaluation of techniques used to adapt the presentation and navigation in educational AHS, using metadata for the learning objects and user modeling, etc, will contribute to improve the value and implementation of e-learning in academics institution, .in a way to make the educational process more adaptive to the student learning style possible.

The capacity of the adaptation of these tools, considering the different necessities and the diversity of individual information source of each student will be necessary, namely for more and more efficiency learning process. It will be also possible to introduce more responsibility to the student in his learning process, namely in the individualization and adaptability of learning.

Also, the application of diverse adaptive techniques in an integrated way for the development of learning tools with constructivist characteristics will be not only an important alternative, but also a new solution/innovation for the learning systems development.

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