A Model of Adaptive e-learning Hypermedia System based on Thinking and Learning Styles

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Abstract

Most approaches to adaptive hypermedia were based around acquiring and representing learner's knowledge. While this is crucial for user modelling in general adaptive hypermedia, it is very limited for e-learning because it does not address the far more fundamental problem which is "learners learn in different ways, different learning styles and different thinking styles".

The design of adaptive e-learning hypermedia system (AEHS) in this work is based on quantitative and qualitative research; the adaptive rules are deduced from the results of a psychological and pedagogical questionnaire. Pedagogical activities are the outcome of a series of deductions; the final activity sets are manifested in AEHS.

In order to assess the positive effect and validity of adaptation on the basis of learners' thinking and learning styles, this study presents two subsequent experiments. The first experiment explores the relationship of thinking style and pedagogical activities to validate this specific psychological construct in the context of educational hypermedia. The second experiment presents the effect of a set of human factors (thinking style, learning style) in AEHS.

Keywords: *Adaptive hypermedia, e-learning, learner model, adaptation model, learning style, thinking style*

1. Introduction

The term of e-learning is becoming increasingly popular in line with the more widespread use of web technology for learning [25]. E-learning is an abbreviation of electronic learning. An e-learning can be defined as a delivery of materials through any electronic media including the internet, intranet, interactive TV, CD-ROM and computer based training. E-Learning plays a major role in delivering educational material to the learners [20].

The advantages of e-learning include classroom and platform independence. Even though currently there are many e-learning systems existing on the web, they commonly present the same materials to all students without considering individual differences [13]. In most web-based courses, the presented materials are only suitable for students who are homogeneous, highly prepared and motivated. When the web-based courses are used by a more diversified student population, it could reach efficiency limits, as these students may have very different learning aims, backgrounds, knowledge levels, learning styles, thinking styles and competencies. A web-based course intended for a certain group of students may not suitable for other students. Therefore a flexible web-based course is urgent to be designed so that different students obtain different learning materials and mode of presentations.

AEHS answer these problems modifying the presentation of materials to adjust each individual student, as well as making make an e-Learning system more effective by adapting the presentation of information and overall linkage structure to individual users in accordance with their knowledge and behaviour [25]. AEHS is based on the assumption that each learner has different learner-characteristics and that different educational settings can be more suitable for one type of learner than for another. When course content can be provided in a flexible way, adapted to individual learners' characteristics through the e-Learning system, the system can deliver the course content so that it capitalizes on the learner's characteristics in order to optimize the learning outcome [5, 6, 24].

The adaptive e-learning hypermedia system (AEHS) also tries to solve the problem of "cognitive overhead" and "lost in hyperspace" mainly when it is applied for large scale learning materials.

There were some studies related to AEHS with different focuses and approaches, one may cite:

- Dall Acqua [10] proposed a multidimensional design model, describing the specifications needed for an educational environment and examined the condition that makes a learning environment "adaptive".
- Dekson and Suresh [12] conducted a survey on the various models of adaptive content delivery system and proposed newer methods of delivering adaptive content for adaptive e-portfolio system.
- Mustafa and Sharif [21] presented an approach to integrate learning styles into adaptive e-Learning hypermedia system and assessed the effect of adapting educational materials individualized to the student's learning style.
- PERSO [9] employs RBC approach (case based reasoning) to determine which courses to suggest to learners based on their knowledge level, and their media preferences.
- TANGOW [22] is based on two dimensions of FSLSM (Felder-Silverman Learning style Model): deductive/ intuitive and sequential/ global. Learners are invited to fill ILS (Index of Learning Styles) assessment when they connect to the system for the first time, the learner‘s model is initialized accordingly. Afterword, learner's actions are monitored by the system, and if they controvert the expected behaviour for these learning preferences, the model is updated.
- WELSA (Web-based Educational with Learning Style adaptation) [23] adopts the unified model of learning style which embeds characteristics of several models proposed in literature, to adapt courses to learners.

According to the overview of AEHS given above, we can conclude that some fundamental short comings of existing models of AEHS are related to:

- The insertion of specific teaching strategies into learning content; specifying a pedagogical strategy in learning content hampers the implementation of interoperability between different e-learning systems and prevents the use of the same teaching strategies for different training materials.
- Use of learning styles in a variety of e-learning systems gives very good results [18, 3], which proves that it can be one of the most effective concepts in modern adaptive hypermedia system. Therefore it is very limited for e-learning because it does not address the far more fundamental problem which is "students learn in different ways and different thinking styles".

- The systems discussed above have no friendly graphical interface that is able to track how the course will be presented to different learners. Most systems provide a scheme of relationships between concepts and learning objects but it is not clear how it will conduct the training process.

Therefore, it can be concluded that it is essential to create a new AEHS model, which should eliminate the disadvantages stated above. Next, the model should serve as a base for the construction of a platform which will be used for practical experiments with e-learning adaptive to thinking and learning styles.

This paper discusses the design of an AEHS based on learner's thinking and learning styles (AEHS-TLS).

2. Thinking's Styles

Each person thinks and behaves in preferred ways that are unique to each individual. These dominant thinking styles are the results of the native personality interacting with family, education, work, and social environments [11, 7]. People's approaches to problem solving, creativity, and communicating with others are characterized by their thinking preferences [15, 17]. For example, one person may carefully analyze a situation before making a rational, logical decision based on the available data. Another may see the same situation in a broader context and look for several alternatives. One person will use a very detailed, cautious, step-by-step procedure. Another has a need to talk the problem over with people and will solve the problem intuitively.

Thought processes have been studied since ancient history, several models have been proposed on how the human brain works. One of the well known models is the Herrmann model [4, 1, 2, 16, 14, 8], which divide the brain into a four quadrant brain dominance model.

These quadrants are located in the left and right hemispheres (left and right brain). The left cerebral hemisphere [Quadrant A] in Herrmann's model is associated with logical, analytical, and quantitative thinking. The left limbic system [Quadrant B] is associated with sequential, organized, and detailed thinking. The right cerebral hemisphere [Quadrant D] is associated with visual, intuitive, and innovative thinking. The right limbic system [Quadrant C] is associated with emotional, sensory, and interpersonal thinking [19].

3. Learning Style

A learning style is defined as the characteristics, strengths and preferences in the way people receive and process information [27]. It refers to the fact that every person has its own method or set of strategies when learning.

We have selected the Felder model as the basis of our approach for the following reasons:

- It has been successfully implemented in previous work when individually adapting the electronic learning material ([26, 28, 29]),
- It has been approved by it's author and other specialists ([30, 27]),
- It is user friendly and the results are easy to interpret,
- The number of dimensions is controlled and can actually be implemented [24].

This model rates the learner's learning style in a scale of four dimensions. Each learning style can be defined by answering these four questions:

- What kind of information does the learner tend to receive: sensitive (external agents like places, sounds, physical sensations), or intuitive (internal agents like possibilities, ideas, through hunches)?
- Through which sensorial channel do the learners tend to receive information more effectively: visual (images, diagrams, graphics), or verbal (spoken words, sounds)?
- How is the information processed: actively (through physical activities and discussions), or reflexively (through introspection)?
- How does the learner make progress: sequentially (with continuous steps), or globally (through leaps and an integral approach)?

4. Architecture of AEHS-TLS

The main characteristic of AEHS-TLS is that it can be adapted to the thinking and learning styles acquired by the learner. The system was organized in the form of three basic components: The domain model, the learner model and the adaptation model. These three components interacted to adapt different aspects of the instructional process. Figure 1 illustrates the system architecture.

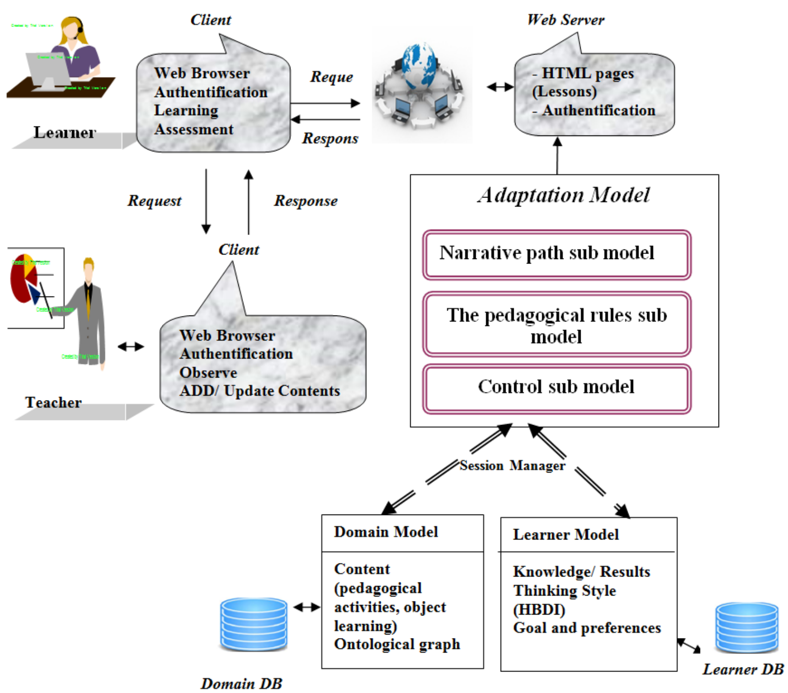

Figure 1. Architecture of AEHS-TLS

4.1. Learner model

A distinct feature of AEHS is the learner model it employs, that is, a representation of information about an individual learner. Learner modelling and adaptation are strongly correlated, in the sense that the amount and nature of the information represented in the learner model depend largely on the kind of adaptation effect that the system has to deliver.

The learner model in our system was defined as three sub models, which are regrouped into ontology:

- **Goals and Preferences**: Stores information which indicates what courses in the system a particular learner wants to visit, what are his/her preferences such as font type, size, colour and other parameters associated with the interface. Furthermore, the preferred courses can be ranked by priority.
- **Thinking and learning style**: it contains information about the specific way of learning of each student and the teaching approach appropriate for him/her.
- **Knowledge and performance**: stores results of tests, projects, tasks, and more. These results are indicators of the student's progress and hence of the effectiveness of the learning process. Furthermore, this model contains the learner's knowledge and knowledge obtained from other sources outside the AEHS-TLS and declared by the learner.

4.2. Domain model

The domain model is used for storage, organization and description of the learning content. This model supports different types of educational content, not just standard narrative content but also pedagogical activities [19].

e activities are categorized in 12 types. For the presentation of theory, eight activities are provided: AG1 (the course structured in learning objectives), AG2 (additional information for the course), AG3 (the course based on examples and analogies), AG4 (multiple-choice questions), AG5 (little theoretical activity), AG6 (little theoretical in groups), AG7 (large theoretical activity), AG8 (large theoretical activity in groups).

Fthe practical application, four activities provided: AG9 (little practical application), AG10 (little practical application in groups), AG11 (great practical), AG12 (great practical in groups).

4.3. Adaptation model

The adaptation model in our system specifies the way in which the learners' knowledge and thinking style modify the presentation of the content. It was implemented as a set of rules. These rules are obtained form the connection between the domain model and learner model to update the learner model and provide appropriate pedagogical activities. It includes the following sub models: narrative paths, pedagogical rules and control (see Figure 1).

4.3.1. The narrative paths sub model: supports a narrative graph, which contains paths different for each thinking style. This graph consists of control points and paths connecting every two control points. In a narrative graph, the teacher can create different path for different thinking styles.

4.3.2. The pedagogical rules sub model: has to submit a set of rules that control learning process. Based on previous results [19], we propose the following pedagogical approach:

Table 1. Pedagogical approach proposed

HBDI Dimension	*Pedagogical approach proposed*
Theorist (blue)	Teachers begin by presenting additional information theory, and they offer individual exercises for learners to make learning easier, after the learners attempt to solve individual problems.
Organizer (green)	Teachers begin by presenting a formal course in several learning objectives, and they offer an overall assessment in the form of multiple choice questions.
Innovator (yellow)	Teachers begin by illustrating it through examples and analogies, then offer individual learners to solve small practical applications, and finally the students are trying to solve large practical applications individually.
Humanitarian (red)	Teachers offer learners to solve small activities theory in groups, then, learners try to analyze and solve big problem in groups, after they go through analysis of small practical applications in groups, therefore the teacher wants the learners to solve large practical applications in groups.

For each activity, the model seeks to adapt the best material to be presented to the learner, observing the following recommendations (see Table 2):

Table 2. Relationship between learning style and course content

Learning Style	*Description*
Active	- Discussion, practice, group work, dialogue. - Including numerous exercises, simulation.
Reflexive	- Working alone - Includes less exercise. - Includes questions that encourage reflection
Deductive	- Includes plenty of facts and practical content. - Give many examples - Includes various multimedia objects
Inductive	- Focusing on abstract concepts and theories - Giving fewer examples
Visual	- Diagrams, pictures, films, demonstrations present the content - using charts and diagrams.
Verbal	- Discussion, oral reports, writing projects, - Includes the text and audio material - Provides opportunities for communication(forum, chat)
Sequential	- Includes content presentation step by step - Puts links to related subjects at the end of the course - Views the 'next' and 'previous' - Hides outline. - Presents the testing in shorter intervals.
Global	- Includes projects and summaries, integrates links to related topical links in the content of the course. - Integrates related topical links in the content of the course. - Places the exercises at the end of the course.

4.3.3. Control sub model: The delivery of pages with learning content to students is controlled by a control sub model which selects the most suitable path (using adaptive navigation) and content (with adaptive selection of content and annotated links), whose presentation is consistent with the corresponding profile of the learner. Instead of dynamically choosing a page (*i.e.*, a node of the graph) with its contents, control sub model selects the most suitable path of the graph for a student with a thinking style on one hand, learning style and level knowledge on the other. For this purpose control points are defined as graph nodes, where control sub model assesses learners' knowledge/results and/or receives data from the learners themselves on the level of satisfaction according his/her goals and preferences. When a learner begins a new course, the control sub model locates the path that is best for him/her in the graph for the corresponding course. The best path for the learner is the one with the greatest weight.

For a learner with given thinking styles, the best path is calculated by the following formula:

$$\underset{(k)}{MAX} \left\{ \sum_{z} (VC\ (z, j) * VS\ (j, l)) / X * Y \right\} \quad , \quad where:$$

- VC (I,j): vector consisting of weights of path I for thinking style j.
- VS(l,j): vector composed of the level at which learner l belongs to thinking style j
- k: the number of path from current control point to next
- X: the length of vector consisting of weights of path I for each thinking style;
- Y: the length of the vector composed of the level at which learner belongs to each of the learning style.

The formula for updating the weight of path, after solving test in next control point, is the following:

$$VC3(k,i) := VC1(k,i) + (VC2(k,i) + VAL * VS(l,i))/N, \text{ where:}$$

- VC1(k,i) : the weight of path k for thinking style originally defined by the teacher
- VC3(k,i) : new weight of path K for thinking style I
- VAL: the result of the test for learner l in next point control
- VS(I,l) : the level at which learner l belongs to thinking style I
- N: the number of learners who passed through the path k until now

When first time learners enter in the system, they signed up to the system by using a registration form. Once a learner registers, a learner profile will be created to store all his information and will be saved in the database, a unique identification (ID) is generated for the learner for further reference and tracking of his progress.

After successful registration, our system shows an introduction page to the learner, explaining the thinking and learning styles categories and their general characteristics. Then it offers two choices either to answer the thinking and learning style questionnaire, or to select his suitable thinking and learning styles based on the provided information.

The thinking and learning style preference is then saved in MySQL database (learner profile) and the learner is re-directed to the learning objective page.

Next, the first lesson is displayed with learning materials and media presentation based on learner profile (see Figure 2, in French).

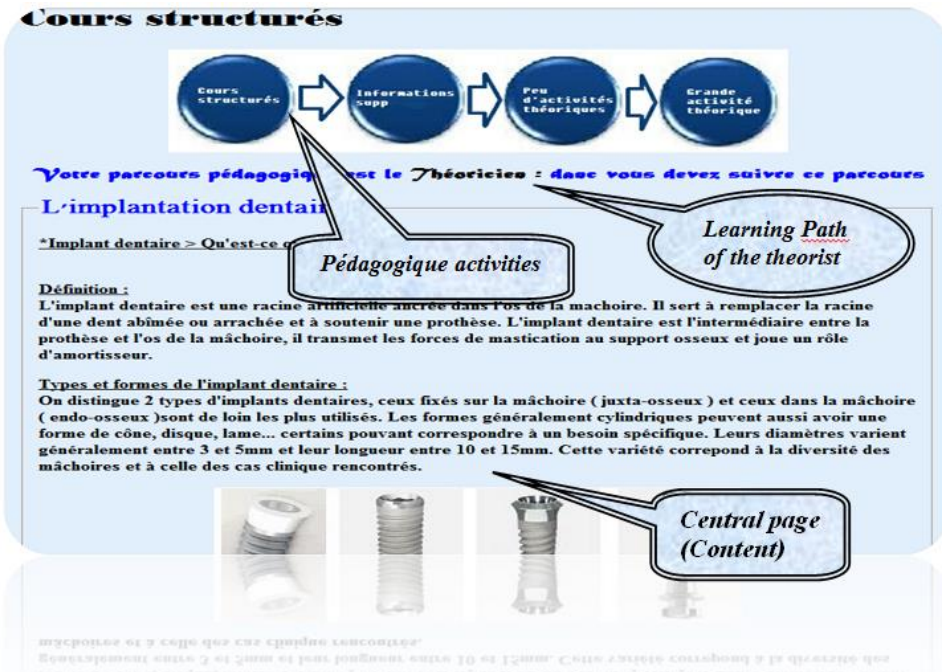

Figure 2. An integrated in adaptive hypermedia system: domain (ORL), thinking style (blue) and knowledge level (average)

5. Experiments

5.1. Context

We conducted an experiment at Annaba University (Algeria), with 40 students for each subjects: "ORL", “dermatology”, “ophthalmology” and “language”. Students can use the system from any computer connected to the university intranet network.

5.2. Participants

Using AEHS-TLS, an experiment was designed to explore the effect of adaptation to different thinking and learning styles and to determine the impact on learning when learning materials were matched with learning preferences. In particular, it was set up to see whether there is a significant difference in learning between two groups, an experimental group who studied with adaptation to thinking and learning styles and a control group who studied with another version of the system without adaptation to thinking and learning styles.

Our hypothesis is this system increases the level of learners.

5.3. Methodology

To verify this hypothesis, we have compared the means of control group and experimental group on the basis on the studied field (ORL, dermatology, ophthalmology, and language). In order to know if the difference is significant between the two means, we have used paired samples t-test (student t-test). After using Matlab software, we have obtained the following results with 95% as significant level (α=0.05):

Table 3 shows the comparison results.

Table 3. Comparison between control and experimental groups depending on the field (ORL, dermatology, ophthalmology, language)

Working domain	Control group		Experimental group		Independent t-test		
	mean	standard deviation	mean	standard deviation	t-test value	degrees of freedom	Probability value
ORL	51.89	10.13	60.90	11.50	-2.629	40	0.0121
dermatology	48.90	12.98	61.47	11.12	-3.289	40	0.0021
ophthalmology	54.20	9.19	62.13	11.20	-2.448	40	0.0189
Language	56.14	12.80	63.76	9.50	-2.135	40	0.0389

From Table 4 of t-test, the difference was very significant, the hypothesis is proved and we can affirm that the system can increase the level of learners in (AEHS- TLS).

6. Conclusion and Future Work

This work delivers educational content adaptively according to each individual learner's thinking and learning styles. The system follows the proposed model of AEHS, which foresees adaptation of teaching material not only to thinking and learning styles but also according to the learner's goals and preferences.

The most important contributions of the present work are as follows:

- Creation of a flexible AEHS model including support of adaptive educational content in each individual learner's style of thinking and learning;
- Design of an architecture of an adaptive e-learning hypermedia system following the proposed model;
- Development of a platform based on the proposed model and architecture;
- Experimental testing and evaluation of the developed prototype.

A useful direction for future development will be the implementation of adaptability according to the learner's goals and preferences. Thus, the model of AEHS-TLS will be reflected fully in the developed AEHS-TLS. Moreover, an important area of adaptability in which the adaptive platform may evolve includes the ability to create adaptive tests. In this way, teachers will have an opportunity for both adaptive content delivery and adaptive evaluation of learners.

Based on an evaluation of the results of system presented in this paper it may be concluded that AEHS-TLS improve essentially the quality and efficiency of e-learning content delivery. Thus, web-based teaching would meet the contemporary needs of modern education in an adequate way. Moreover, this system allows combining traditional e-learning materials with educational games, which is a promising and fast growing research trend as well as market area. Including serious games into the e-learning process makes it more attractive and immersive for all types of students.

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