

An Adaptive E-Learning System based on Student's Learning Styles: An Empirical Study

Samia Drissi, Badji Mokhtar-Annaba University, Annaba, Algeria & Faculty of Science and Technology, University of Souk-Ahras, Souk-Ahras, Algeria

Abdelkrim Amirat, Faculty of Science and Technology, University of Souk-Ahras, Souk-Ahras, Algeria

ABSTRACT

Personalized e-learning implementation is recognized as one of the most interesting research areas in the distance web-based education. Since the learning style of each learner is different one must fit e-learning with the different needs of learners. This paper presents an approach to integrate learning styles into adaptive e-learning hypermedia. The main objective was to develop a new Adaptive Educational Hypermedia System based on Honey and Mumford learning style model (AEHS-H&M) and assess the effect of adapting educational materials individualized to the student's learning style. To achieve the main objectives, a case study was developed. An experiment between two groups of students was conducted to evaluate the impact on learning achievement. Inferential statistics were applied to make inferences from the sample data to more general conditions was designed to evaluate the new approach of matching learning materials with learning styles and their influence on student's learning achievement. The findings support the use of learning styles as guideline for adaptation into the adaptive e-learning hypermedia systems.

KEYWORDS

Adaptive Learning, Honey and Mumford Model, Learning Achievement, Learning Style, Personalization

1. INTRODUCTION

Adaptive educational hypermedia systems try to offer an alternative to the non-individualized approach, by providing various services adapted to the learner profile. So, Web-based adaptive e-learning hypermedia systems aim to provide content that fits the individual learning preferences of students. They reflect characteristics of users in a user model and apply that model to adapt instructional aspects of the system accordingly (Brusilovsky, 1996). In this regard, these systems can be considered an extension of intelligent tutoring systems. Like intelligent tutoring systems Web-based adaptive e-learning hypermedia adapts instruction on a micro-level through identifying individual learner needs and providing instructional prescriptions accordingly (Lee & Park, 2008). These prescriptions can be presentation or navigation support (Brusilovsky, 2001). In addition, these systems not only allow users to initiate their choices of instruction, but also provide them with opportunities to use outer web resources. Thus, they are not "closed corpus systems confined to the program" (Lee & Park, 2008, p. 471). With these capabilities they can be used to avoid the one-size-fits-all approach and to create the optimum online lesson for learners with diverse learning needs (Brown, Cristea, Stewart, & Brailsford, 2005).

A number of adaptive educational hypermedia systems have been developed to support learning style as a source for adaptation. AEC-CS (Triantafillou, Pomportis, & Demetriadis, 2003), INSPIRE (Papanikolaou, Grigoriadou, Kornilakis, & Magoulas, 2003) and ILASH (Bajraktarevic, Hall, & Fullik, 2003) are some of examples that are worth citing. However, most of these systems lack the experimental evaluation to assess their impact on student's achievement. Most of the attempts in this area are based on their adaptation to the user's level of knowledge (Stash & De Bra, 2004). Other learning features were taken into account such as background, hyperspace experience, preferences and interests (Brusilovsky, 2001; Popescu et al., 2007). However, little interest was paid to learning styles and their effects on learning achievement. This is despite the fact that learning styles constitute a valuable tool for improving individual learning among the user features (Paredes & Rodriguez, 2002). Statistics revealed that students' learning style can be considered as significant factor that improves the learning performance in web-based learning or e-learning (Manochehr, 2006).

Because of this lack of experimental studies, we attempt in this research study to answer a clearly defined need namely to assess the contribution of the adaptation of a course based on the learning style of the learner in the context of the self-learning via the Web. This article focuses on the proposal for a set of adaptation rules that will be used to adapt the presentation and navigation of an educational hypermedia, while based on the Honey and Mumford model. The main objectives were to evaluate the new approach of matching learning materials with learning styles and their influence on student's learning achievement. Inferential statistics were used in the form of independent sample t-test to make inferences from the data to more general conditions.

Consequently, in this paper, we have reformulated the problem by setting the following scientific objectives:

- Adopt the experiential learning theory for the design of a dynamic adaptive hypermedia while determining a learner model and a domain model according to this theory.
- Provide an adaptation based on the learning styles of learners to adapt the presentation of pages and links of a hypermedia course using the sequencing and annotation links (scheduling a link in the cycle of experiential learning and an annotation using icons to give learners an idea on the subject to present, based on the model of Honey and Mumford).
- Provide a general description to describe educational resources appropriate for each stage of experiential learning and for each learning style.
- Determine the adaptation rules for each learning style respecting each phase of experiential learning.
- Provide an evaluation module for learners to assess and test their knowledge levels after learning of a particular chapter from courses tailored to their learning styles.
- Finally, evaluate the performance of our system to validate or invalidate the contribution of learning styles in the adaptation process.

The rest of the paper is structured as follows: the next section gives an overview of adaptive educational systems that focus on the learning style of the learners. Section 3 describes the Honey and Mumford's learning style model that will be adopted in our research. Next, in section 4, we illustrate the architecture of our system and we introduce our own approach to elaborate the adaptation rules. And in section 6, we evaluate our approach. Finally, conclusion and some future works are presented in section 7.

2. RELATED RESEARCH

Learning style-based adaptive educational systems (LS-AES) are a special case of adaptive educational systems which focus on students' learning preferences as the adaptation criterion. At present, there is a large number of learning style models proposed in the literature (over 70 according to (Coffield, Moseley, Hall and Ecclestone, 2004)), which differ in the learning theories they are based on, the number and the description of the dimensions they include. While some of these models suffer either low internal reliability or the lack of empirical support, some are perceivably more robust and commonly used in the learning style research for decades (e.g. Dunn & Dunn, 1974; Felder & Silverman, 1988; Honey & Mumford, 1982; Kolb, 1984; Pask, 1976).

According to (Akbulut & Cardak, 2012), the most preferred learning style model was Felder–Silverman Learning Style Dimensions, which was utilized in 35 studies among 70 studies (50%), followed by cognitive styles (17.1%), Kolb (8.6%), VARK (7.1%), Honey and Mumford (5.7%) and other individual models such as Dunn and Dunn's (1974) and Keefe's (1987). Also according to (Akbulut & Cardak, 2012), major purposes of the studies were classified, 41 studies among 70 studies of which (58.6%) aimed to propose a framework or model for adaptivity.

Moreover, few experimental studies were conducted to investigate the effectiveness of matching learning materials to user's learning style. Most of the analysis these studied was descriptive statistics, which basically aim to quantitatively summarize a sample data set, rather than being used to support inferential statements about the entire population that the data are thought to represent.

In this respect, Brown et al. (2009) investigated adaptive e-learning hypermedia that utilizes learning style as their adaptation mechanism. They found that out of ten systems, six systems did not seem to have published any quantitative evaluations. Two systems: AES-CS (Triantafyllou, Pomportis, & Demetriadis, 2003) and INSPIRE (Papanikolaou, Grigoriadou, Kornilakis, & Magoulas, 2003) presented some empirical data in the form of descriptive statistics and no inferential statistics testing was carried out.

Mampadi, Chen, Ghinea and Chen (2011) developed an adaptive hypermedia learning system tailored to students' cognitive styles with an emphasis to Pask's Holist-Serialist dimension. In this study, they examined the students' reaction to the system in terms of learning performance and perception. Students are asked to answer a set of questionnaire and based on the result of the survey they are then categorized into Serialists or Holists. Half of the group in both Serialists and Holists were asked to use the adaptive hypermedia system (AHLS) and the other half were asked to use the ordinary hypermedia system without the adaptation (OHLS). Students were required to take the pre-test and post-test so that their levels of knowledge of the subject domain can be assessed. The results of the experiment showed that the students using AHLS showed better performance and bigger improvement than those using OHLS regardless of their cognitive styles. Both Serialists and Holists using AHLS also demonstrated more positive perceptions towards structure clarity and logical sequence than those using OHLS.

Recently, Hwang, Sung, Hung and Huang (2013) developed an adaptive learning system based on the sequential-global dimension of Felder–Silverman's learning style theory for an elementary school natural science course. From a practical application, they reported that the students who learned with the adaptive learning system showed better learning achievements and attitudes than those who learned with a conventional e-learning system.

Also, Yang, Hwang and Yang (2013) developed an adaptive learning system by taking multiple dimensions of personalized features into account. A personalized presentation module is proposed for developing adaptive learning systems based on the field dependent/independent cognitive style model and the eight dimensions of Felder-Silverman's learning style. An experiment has been conducted to evaluate the performance of the proposed approach in a computer science course. Fifty-four participants were randomly assigned to an experimental group which learned with an adaptive learning system developed based on the personalized presentation module, and a control group which learned with the

conventional learning system without personalized presentation. The experimental results showed that the experimental group students revealed significantly better learning achievements than the control group students, implying that the proposed approach is able to assist the students in improving their learning performance. Table 1 gives a summary of the analysis approaches used by these systems.

The summary of the analysis approaches in (LS-AES) cited above shows that the most widely used evaluation approach is to compare adaptive with non-adaptive versions of the whole system. Consequently, any difference between the two approaches might be attributed to users' features other than learning styles like adaptation to user's knowledge, goals etc. Moreover, in most evaluations of adaptive systems, the adaptive application is usually built first and then a second version is generated from the adaptive one. The two versions are then compared through user testing. This is not a fair comparison because the non-adaptive version of the application is not well designed and thus put at a disadvantaged side right from the start (De Bra, 2000). Triantafillou et al. (2002) developed a prototype system to test the hypothesis that cognitive learning styles could benefit learning outcomes. They conducted a small scale experiment to evaluate learner's performance. Only descriptive statistics in the form of mean and standard deviation was used. In Papanikolaou et al. (2003) authors performed an empirical study to evaluate the adaptation framework and assess learners' attitudes towards the proposed instructional design. The number of students involved in the experiment was 23, which is still relatively small. They used descriptive statistics analysis in the form of bar and line charts.

To overcome this problem, in this research we will implement and evaluate a new Adaptive Educational Hypermedia System based on Honey and Mumford learning style model (AEHS-H&Mq). Our choice of this model is justified firstly because this learning model is assumed to be acquired preferences that are adaptable, whether at will or through changed circumstances rather than being fixed personality characteristic (Anthony, Joseph, & Ligadu, 2013), secondly because the Honey and Mumford's model is based on a comprehensive theory of learning that is the Experiential Learning Theory (ELT) which will be detailed in the following section. And finally, we justify our choice for the use of Honey and Mumford model because all empirical studies around this model are presented in the form of descriptive statistics and no inferential statistics testing was carried out as in the case of INSPIRE (Papanikolaou, Grigoriadou, Kornilakis, & Magoulas, 2003).

Table 1. Summary of the analysis approaches in (LS-AES)

| Paper | Learning style model | Analysis approach | Number of sample |
|---|---|--|------------------|
| AES-CS (Triantafillou, Pomportis, & Demetriadis, 2003) | Field dependence/independence (FD/FI) of cognitive styles | Descriptive statics in the form of mean and standard deviation | 68 participants |
| INSPIRE (Papanikolaou, Grigoriadou, Kornilakis, & Magoulas, 2003) | Honey and Mumford | Descriptive statistics were used in the form of bars and line charts | 23 participants |
| Mampadi, Chen, Ghinea and Chen (2011) | Pask's Holist-Serialist dimension | Inferential statics used the t-test analysis. | 44 participants |
| Hwang, Sung, Hung and Huang (2013) | sequential/global dimension of Felder and Silverman model | Inferential statics used the Chi-square analysis | 228 participants |
| Yang, Hwang and Yang (2013) | field dependent/independent cognitive style model and the eight dimensions of Felder-Silverman's learning style | Inferential statics used the t-test and ANCOVA analyses | 54 participants |

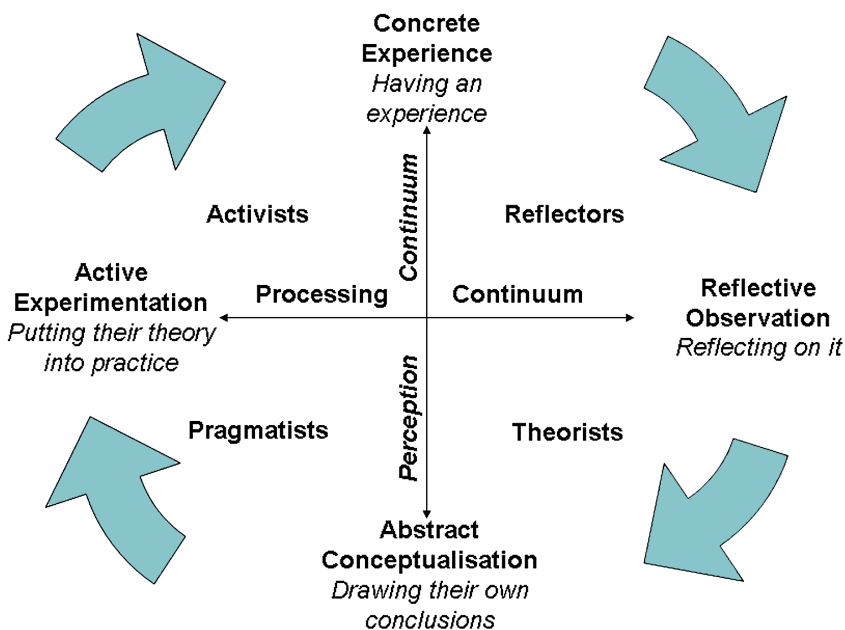
3. HONEY AND MUMFORD'S MODEL

The Honey and Mumford's model differs from other learning style model used in education by being based on a comprehensive theory of learning and development. This model adopts the Experiential Learning Theory (ELT) in the context of the DAVID KOLB's model.

Experiential learning theory (ELT) defines learning as “the process whereby knowledge is created through the transformation of experience. Knowledge results from the combination of grasping and transforming experience” (Kolb 1984). The ELT model portrays two dialectically related modes of grasping experience: Concrete Experience (CE) and Abstract Conceptualization (AC) and two dialectically related modes of transforming experience: Reflective Observation (RO) and Active Experimentation (AE). Experiential learning is a process of constructing knowledge that involves a creative tension among the four learning modes that is responsive to contextual demands. This process is portrayed as an idealized learning cycle or spiral where the learner “touches all the bases”: experiencing, reflecting, thinking, and acting in a recursive process that is responsive to the learning situation and what is being learned. Concrete experiences are the basis for observations and reflections. These reflections are assimilated and distilled into abstract concepts from which new implications for action can be drawn. These implications can be actively tested and serve as guides in creating new experiences (see Figure 1).

Honey and Mumford adapted the experiential model which identifies four types of learners called theorist, reflector, activist and pragmatist. Theorists like to understand the theoretical aspect behind all actions. They need concepts, models and facts as their learning process. They prefer to analyze and synthesize every bit of new information in a systematic and logical manner. Reflectors learn by observing and by reflecting each learning outcome or goal. They are not spontaneous but prefer to stand back and view experiences from a number of perspectives, collecting data and taking time to find an appropriate conclusion. Activists are learners who learn by doing and discover things for themselves. They need to get practical and get their hands dirty in learning a certain concept. Finally, pragmatists need to be able to see how to put the learning into practice in the real world. They like

Figure 1. The experiential learning cycle and basic learning styles



to see the relevance and real world applicability to whatever they are learning. The description of these styles is given in Table 2.

4. ARCHITECTURE OF THE PROPOSED SYSTEM

The main characteristic of our system (AEHS-H&M) is that it can be adapted to the student learning style. The system was organized in the form of four basic components: The learner model, the domain model, the adaptation module and the evaluation module. These four components interacted to adapt different aspects of the instructional process. Figure 2 illustrates the system architecture.

Apache, MySQL database and PHP language server have been used in order to develop the system. These technologies were used because of their faster reaction for dynamic web application and because the communication between them tends to be perfect. AEHS-H&M utilized the following software versions:

- Apache 2.2.8
- MySQL 5.0.51a
- PHP 5.25
- Windows XP/Vista
- Hot Potatoes 6

5. LEARNER MODEL

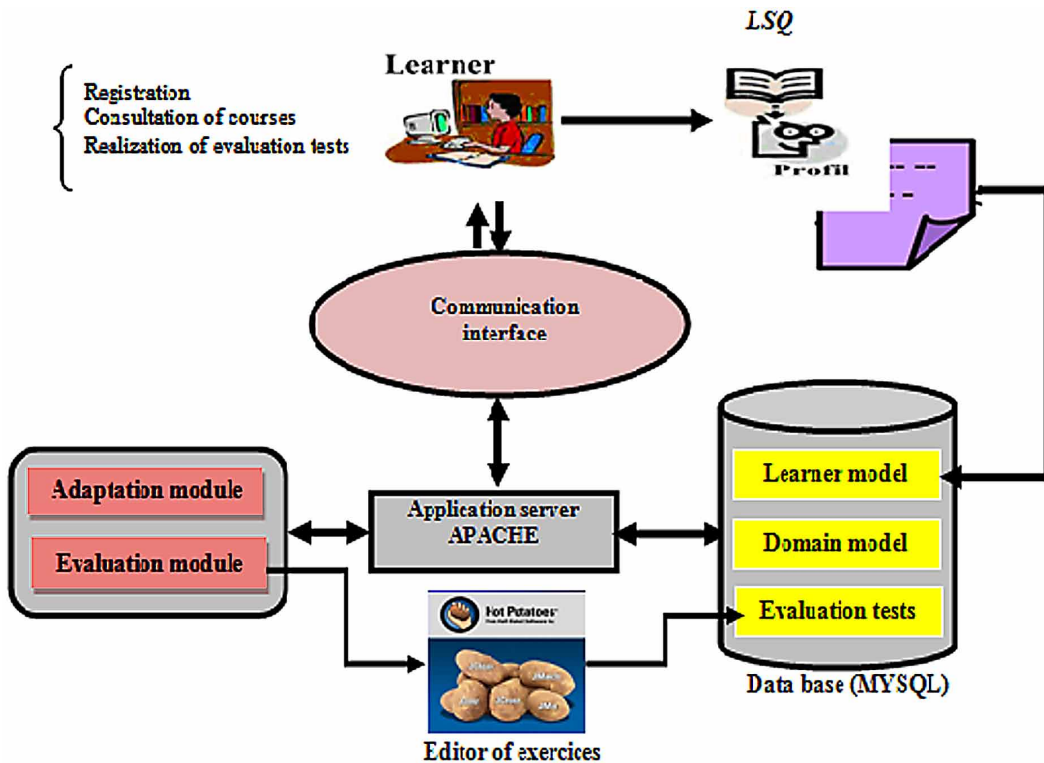
In AEHS-H&M, to model our learner we will follow two phases:

Phase 1: In our approach, the learner can be modeled first by the typical characteristics that are grouped in a facet identification that contains personal data for example username, password, unique ID, age, sex, e-mail. These data are obtained using a questionnaire that the learner must complete on their initial login.

Table 2. Description of the Honey and Mumford's learning styles

| Learning style | Description |
|---|--|
| Activists /Concrete Experience | <ul style="list-style-type: none"> ■ Who are flexible and open-minded, ready to take action and like to be exposed to new situations. ■ They sometimes take unnecessary risks, rush into action without sufficient preparation and get bored with the implementation / follow through. |
| Reflectors / Reflective Observation | <ul style="list-style-type: none"> ■ Who are careful, thorough, methodical, good at listening to others and assimilating information; sometimes they tend to be too cautious and not take enough risks, to hold back from direct participation and they may be slow to make up their minds and reach a decision. ■ Prefer to learn from activities that allow them to watch, think, and review (time to think things over) what has happened. Likes to use journals and brainstorming. |
| Theorists / Abstract Conceptualization | <ul style="list-style-type: none"> ■ Who are very logical, rational and objective, they are good at grasping the big picture and have a disciplined approach; they are intolerant of anything subjective or intuitive and have low tolerance for uncertainty, disorder and ambiguity. |
| Pragmatists / Active Experimentation | <ul style="list-style-type: none"> ■ Who are practical, businesslike, technique-oriented, they want to test things out in practice and get straight to the point; they are not interested in theory or basic principles and tend to reject anything without an obvious application; they are impatient with decisions and more task-oriented than people-oriented. ■ They like laboratories, field work, and observations. Likes feedback, coaching, and obvious links between the task-on-hand and a problem. |

Figure 2. Architecture of the proposed system (AEHS-H&M)



Phase 2: Selection of learning styles of learners is performed using the instrument of Learning Style Questionnaire (LSQ) of Honey and Mumford which is used to categorize the students into four learners type (Theorist, Reflector, Activist and Pragmatist) (Honey and Mumford, 2006) . Figure 3 illustrated the learner model established by the LSQ instrument.

6. DOMAIN MODEL

According to (IMS MD, 2008), learning objects represent any digital resources that can be reused to support learning. In our case, the most complex learning object (with the coarsest granularity) is the course, while the finest granularity learning object is the elementary educational resource. We have conceptualized the learning material using the hierarchical organization illustrated in Figure 4: each course consists of several chapters, and each chapter can contain several sections and subsections.

The lowest level subsection contains the actual educational resources. Each such elementary learning object corresponds to a physical file and has a metadata file associated to it. This fine grained representation of the learning content is needed to insure the adaptation and modeling requirements.

Figure 3. Learner model established by the LSQ instrument

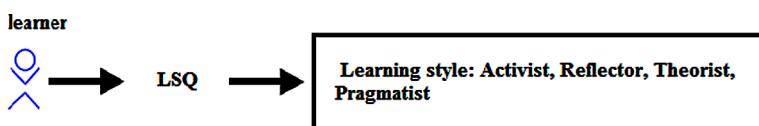
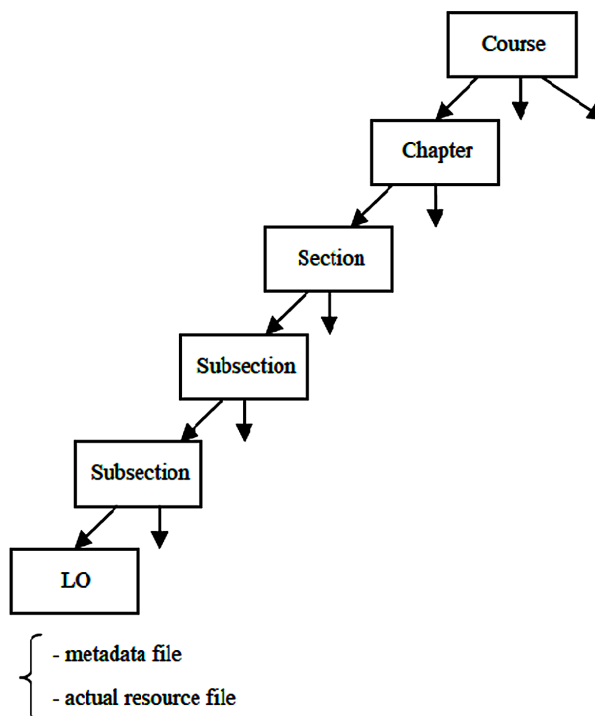


Figure 4. Organization of domain model



To make an association between this model of domain and the four phases of the experiential learning model, we are going to use four types of learning objects to teach every concept of a given course. Then the conception of these learning objects was adopted in the following way:

- **Exploratory Learning Objects:** Associated with the phase of the Concrete Experience (CE), they allow describing in a concrete way some lived experiences, these exploratory learning objects help well teaching the exploration of a concept. Then this type of learning objects is recommended for the exploratory mode. Exploratory learning objects can be represented for example by the case studies or by the filmed experiences.
- **Illustrative Learning Objects:** (Example, illustration, comparison, analogy either against examples) associated with the phase of the Reflective Observation, these illustrative learning objects allow the learner the reflection, the observation and the accumulation of data before emitting an opinion. Then these examples are recommended for the reflective mode.
- **Theoretical Learning Objects:** Reinforced by theoretical presentation associated with the phase of the abstract conceptualization. Then these theoretical presentations are recommended for the abstract mode.
- **Interactive Learning Objects:** (An interactive simulation, resolution of problem, exercise) associated with the phase of the active experimentation; they allow the learner the application and the try of the knowledge and the ideas. These interactive learning objects are recommended for the verification mode.

7. ADAPTATION MODULE

The adaptation module is responsible for a concept chosen by the learner, the dynamic construction of a hypermedia page, depending on the current state of the domain model and learner model.

Our AEHS-H&M possess the ability to make intelligent decisions about the interactions that take place during learning aiming to support learners without being directive. This functionality employs the underlying learner model of the system in a number of ways: adaptive navigation support, and adaptive presentation.

Firstly, in AEHS-H&M, the adaptive navigation support technology is mainly implemented by adaptation module through adaptive ordering technique that focuses on ordering the links and through visual adaptive annotation of links. The adaptive ordering technique gives the learner a hint which of these links to follow. In our system, the adaptive ordering technique applies learner learning style based on Honey and Mumford model to adapt the order of presentation for all possible links according to the cycle of experiential learning theory. While, visual adaptive annotation of links can give the learner some additional information about accessible learning objects and thus reduce their floundering in the hyperspace. In our system, we use icon based annotations. Secondly, AEHS-H&M implemented adaptive presentation by classifying learners according to their current learning styles. Learners with different learning styles view different presentation of the same learning objects depending on the combination of different media (text, image, sound, and video) and different content (examples, exercises, simulations...). So, in this research, four (4) learning modes are generated: exploratory mode, reflective mode, abstract mode and verification mode.

- **Exploratory Mode:** This mode is designed for activist learners. It begins with exploratory learning objects displayed in full screen, followed by a first link to illustrative objects, and a second link to the abstract objects, and finally a link to the interactive objects.
- **Reflective Mode:** This mode is designed for reflector learners. It begins with reflective objects displayed in full screen, followed by a first link to abstract objects, and a second link to interactive objects, and finally a link to exploratory objects.
- **Abstract Mode:** This mode is designed for theorist learners. It begins with abstract objects displayed in full screen, followed by a first link to interactive objects, and a second link to exploratory objects, and finally a link to illustrative objects.
- **Verification Mode:** This mode is designed for pragmatist learners. It begins with interactive objects displayed in full screen, followed by a first link to exploratory objects, and a second link to reflective objects, and finally a link to abstract objects.

Consequently, to support adaptivity in AEHS-H&M, the adaptation module specified the way in which learners' learning style modify the presentation of content and links. It was implemented as a set of the classical structure: if condition, then action type rules. These adaptation rules form the connection between the domain model and learner model to update the learner model and provide appropriate learning objects.

In this paper, our adaptation module is interested in the Honey and Mumford model and in the cycle of experiential learning theory for the definition of a set of adaptation rules. Then, before elaborating adaptation rules, we will first associate for each learning style general rule and secondly, we will describe the specific adaptation rules that will be used by the adaptation module. Table 3 describes general rules and specific rules used by adaptation module.

Table 3. General rules and specific rules described using Honey and Mumfor's model

| | |
|-----------------------|--|
| General rules | <p>If LS^{"H&M"} (learner)= "activist" Then apply exploratory mode Else if LS^{"H&M"} (learner)= "reflector" Then apply reflective mode Else if LS^{"H&M"} (learner)= "theorist" Then apply abstract mode Else if LS^{"H&M"} (learner)= "pragmatist" Then apply verification mode</p> |
| | <p>Adaptation rule for activist learner If LS^{"H&M"} (learner) = "activist" Then Appear in the top of page exploratory learning objects followed by <u>links</u> to illustrative learning objects, theoretical learning objects and interactive learning objects.</p> |
| | <p>Adaptation rule for reflector learner If LS^{"H&M"} (learner) = "reflector" Then Appear in the top of page illustrative learning objects followed by <u>links</u> to theoretical learning objects, interactive learning objects and exploratory learning objects.</p> |
| Specific rules | <p>Adaptation rule for theorist learner If LS^{"H&M"} (learner) = "theorist" Then Appear in the top of page theoretical learning objects followed by <u>links</u> to interactive learning objects, exploratory learning objects and learning objects.</p> |
| | <p>Adaptation rule for pragmatist learner If LS^{"H&M"} (learner) = "pragmatist" Then Appear in the top of page interactive learning objects followed by <u>links</u> to exploratory learning objects, illustrative learning objects and theoretical learning objects.</p> |

LS^{"H&M"}: learner's learning style described using Honey and Mumford's model.

8. EVALUATION MODULE

This module allows offering to the learners a set of evaluation tests in order to evaluate their knowledge after a chapter already completed. Our evaluation module provides learners different types of exercises including: multiple choice questions (MCQ) and matching questions.

- **Multiple Choice Questions (MCQ):** Following items including a question whose answer is found among several answers given.
- **Question to Matching:** This type of question has two lists of words that the student is asked to bind in pairs.

In our system, evaluation tests were automatically generated using an editor of exercises called Hot potatoes that is a software suite includes five applications to create exercises to upload on the web. Applications are called: JQuiz editor (multiple choice questions or MCQs), JCloze, JCross (crossword editor) JMix and JMatch (Editor of matching exercises).

9. EVALUATION OF OUR SYSTEM

The main objective of this research is to answer the following question: Introducing learning styles in Adaptive E-learning Hypermedia Systems can improves learner's achievements and performance?

In order to answer the previous question, using our AEHS-H&M, an experiment for a period of five months during a normal semester was designed to explore the effect of adaptation to different learning styles and to determine the impact on learning achievement when learning materials were matched with learning preferences. In particular it was set up to see whether there is a significant difference in learning achievement between two groups, an experimental group who studied with adaptation to learning styles and a control group who studied with another version of the system without adaptation to learning styles.

Hypermedia in which we applied our experiment is derived from chemistry course focused “on fast reactions and slow reactions”. When first time learners enter AEHS-H&M, 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/her information and will be saved in the database, a unique identification (ID) is generated for the learner for further reference and tracking of his/her progress.

9.1. Participants

So, before discussing our online experiment, sixty (60) students were randomly selected to take part in this experiment. All were first year students at the College of Sciences and Technology at Souk Ahras University (Algeria). The students are novices in the field of chemistry. Therefore, they had no pre-requisites of the “fast reactions and slow reactions” course. The participants were randomly divided into two groups which are the experimental group (n = 30) and the control group (n = 30). Table 4 shows the distribution of students across the two groups.

9.2. Learning Activity Design

Figure 5 shows the procedure of the experiment. In the first stage, the students were instructed in the basic knowledge of “fast reactions and slow reactions”. After receiving this fundamental knowledge, the students were asked to take a pre-test, which aimed to evaluate their basic knowledge before participating in the learning activity.

In the second stage, the students in the experimental group were arranged to learn with the AEHS-H&M system; that is, they were provided with an adaptive version by taking both their learning styles into account. The adaptive version can be presented to experimental group through four modes: exploratory mode, reflective mode, abstract mode or verification mode. On the other hand, the students in the control group learned with another version of the system without adaptation to learning styles. After conducting the learning activity, the students took a post-test and answered a post-questionnaire.

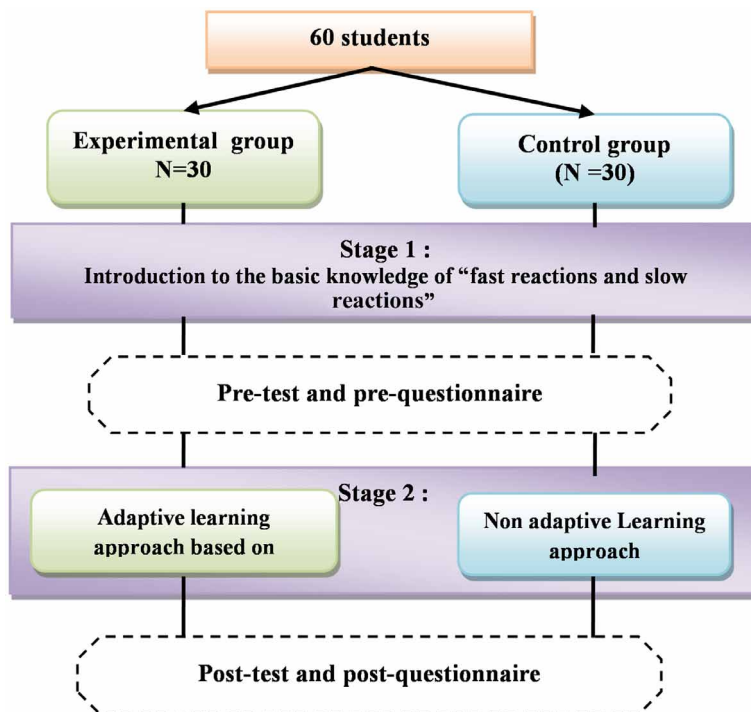
9.3. Research Instruments

Four testing instruments were used in this experiment. The first was a questionnaire designed to collect data about students’ demographic and academic background. The second was the Learning Style Questionnaire (LSQ) of Honey and Mumford, which was used to determine the learning style of the participants. The third was a post test questionnaire and a pretest questionnaire conducted to assess participant’s levels of knowledge of the subject domain both before and after using the system. The fourth was an attitude and acceptance questionnaire for the experimental group that included items related to the completeness and ease of use of the system, and also items on subject’s satisfaction and willingness to use the system in the future.

Table 4. Division of learners

| Learning style types | Experimental group | Control group | Total |
|----------------------|--------------------|---------------|-------|
| Activists | 06 | 06 | 12 |
| Reflectors | 12 | 12 | 24 |
| Theorists | 07 | 07 | 14 |
| Pragmatists | 05 | 05 | 10 |
| Total | 30 | 30 | 60 |

Figure 5. Procedure of the experiment



10. RESULTS AND DISCUSSION

10.1. Results Specific to Demographic and Academic Background Questionnaire

Table 5 shows the demographics and the frequency of control and experimental group's responses.

The experimental group consisted of 6 (20%) male and 24 (80%) female students. The mean age was 18.9 with a standard deviation of 0.44. The control group consisted of 12 (40%) male and 18 (60%) female students. The mean age was 19.1 with a standard deviation of 0.44.

10.2. Results Specific to Pre-Test

The independent sample t-test was performed first in order to determine whether the control group and experimental groups had the same prior knowledge on studied domain. As can be seen in Table

Table 5. Demographic data and student's characteristics

| Items | Choices | Control group | | Experimental group | | Total | |
|----------|----------|---------------|------|--------------------|------|-------|------|
| | | F | % | F | % | F | % |
| Sex | Male | 12 | 40 | 6 | 20 | 18 | 30 |
| | Female | 18 | 60 | 24 | 80 | 42 | 70 |
| Age | 18 years | 11 | 36.7 | 14 | 46.7 | 25 | 41.7 |
| | 19 years | 09 | 30 | 08 | 26.7 | 17 | 28.3 |
| | 20 years | 07 | 23.3 | 05 | 16.6 | 12 | 20 |
| | 21 years | 03 | 10 | 03 | 10 | 06 | 10 |
| Mean age | | M=19.1 | | M=18.9 | | M= 19 | |

F = Frequency, % = Percentage

6, there was no significant differences between the experimental group and the control group in their prior knowledge ($P > 0.05$). This result implying that these two groups did not significantly differ prior to the experiment. That is, the two groups of students had statistically equivalent abilities before taking the subject unit.

10.3. Results Specific to Post-Test

The hypothesis of the research is:

Null hypothesis H_0 : the use of the learning styles as adaptivity in Adaptive E-learning Hypermedia Systems cannot improve student’s achievement and performance.

In order to verify our hypothesis, we calculated the difference of the achievement results of the students. For doing this, each student must answer the post-test questionnaire. As we have the different sample of student who used the system in this level of post-test questionnaire and the number of the learner of each group is not greater than thirteen (30), we used the independent t-test of student. Before using the independent t-test of student, we must ensure that the data are normally distributed. For doing this, we have used Shapiro- Wilk test.

The independent sample t-test was performed to compare the mean scores for the two groups in post test results. The t-test determined that the differences measured between the means of the control and experimental group were significantly different and could be attributed to the learning through learning styles adaptation given to the experimental group. Results show the experimental group performed significantly better than the control group in the post test questionnaire ($t = -3.29$, $df = 58$, $p = 0.0017 < 0.05$).

Table 7 shows the comparison results, the difference was statically significant; therefore the null hypothesis H_0 is rejected. So, the alternative hypothesis is proved and we can affirm that “the use of learning styles in Adaptive E-learning Hypermedia Systems as criterion of adaptation improves the achievement and performance of students“.

Achievement results obtained clearly show that introducing learning styles as adaptivity in Adaptive E-learning Hypermedia System improves students’ achievement and performance. The findings agreed with previous study from Bajraktarevic et al. (2003). Their results show that all students achieved significantly higher scores with matched materials. However, their sample size is relatively small (22 students). The results also agreed to those of Triantafillou et al. (2003) and Papanikolaou et al. (2003) who use only descriptive statistics in the form of charts and frequency tables. Brown et al. (2007) reported contradictory results. They find that there is no evidence to support the theory that matching users’ learning styles has any impact on making learning more effective. However, their

Table 6. Independent t-test on the pre-questionnaire of the experimental group and the control group

| Control group | | Experimental group | | Independent t-test | | |
|---------------|-------|--------------------|-------|--------------------|----|---------|
| Mean | SD | Mean | SD | t | df | P-value |
| 63.94 | 15.53 | 64.76 | 13.40 | -0.215 | 58 | 0.831 |

SD: standard deviation, t: t-test value, df: degree of freedom, P-value: probability value

Table 7. Independent t-test on the post-questionnaire of the experimental group and the control group

| Control group | | Experimental group | | Independent t-test | | |
|---------------|-------|--------------------|-------|--------------------|----|---------|
| Mean | SD | Mean | SD | t | df | P-value |
| 69.42 | 12.05 | 78.63 | 09.12 | -3.29 | 58 | 0.0017* |

*Significant difference, SD: standard deviation, t: t-test value, df: degree of freedom, P-value: probability value

sample was children in primary school. Consequently it was difficult to assess the learning styles of 9-11 year old children. In another study Brown et al. (2006) found that using matched or mismatched learning materials does not significantly benefit nor disadvantage the students. Their results attribute to the learning style preferences studied in their experiment which are constrained only to visual and verbal perspectives. So, our results are consistent with those published in (Popescu, 2008, 2010), (Eltigani, Mustafa, & Sharif, 2011), (Anthony, Joseph, & Ligadu, 2013) and (Yang, Hwang, & Yang, 2013). Which show that during the adaptation of course based on learners learning styles improved their scores. Contrariwise, our results are inconsistent with those published in (Brown et al., 2006; Siadaty & Taghiyareh, 2007; Wolf, 2007) which prove that learning style based on adaptive e-learning hypermedia systems did not have significant effects on learning outcomes.

10.4. Results Specific to Attitude and Acceptance Questionnaire

For the facility of navigation in system, Table 8 signifies the appreciation degree, that is how easy to navigate various learning objects for generating their courses. 74% of the experimental group feel very convenient or convenient when navigate in our system; besides the 26% of the same group who feel the navigation is not convenient. Overall, these results show that the majority of learners in the experimental group (75%) state that the adaptation of courses to learning styles was generally useful, against only 25% of the same group who indicated that this adjustment was unfavorable. The students were satisfied to learn with the preferred learning style and willing to use our system in the future.

So, our results are consistent with those published in (Cabada et al., 2011; Mampadi et al., 2011; Papanikolaou et al., 2003; Popescu, 2010; Sangineto et al., 2008; Schiaffino et al., 2008) which show that during the adaptation of course based on learning styles Students' satisfaction levels were higher.

11. CONCLUSION

In this paper, we presented the design and modeling of an adaptive e-learning hypermedia system focused on learning styles. We also attached great importance to the design of learning activities (exercise, examples, simulation, etc.), as these should reflect the dimensions related to different learning styles adopted in our system.

Findings showed that students taught using the system with adaptation to learning style performed significantly better in academic achievement than students taught the same course without adaptation to learning style ($p < 0.05$). So, the findings supported the use of learning styles as guideline for adaptation into the adaptive e-learning hypermedia systems.

The present study shows fruitful results but there are several limitations. For example, the present study only incorporated a small-scale sample and learning content. Hence, it is recommended that further studies should be undertaken with a larger sample and content to provide additional evidence.

Table 8. Student's ratings about several aspects and adaptation features of system

| Statement | Percentage (%) | |
|---|----------------|----|
| | Yes | No |
| 1) The presentation of the entire content into different learning objects (exploratory learning objects, illustrative learning objects, theoretical learning objects, interactive learning objects) helped in my understanding? | 67 | 33 |
| 2) The link adaptation through link annotation to adapt the navigation according to learners learning style facilitates my orientation and navigation in the lesson contents and supports my understanding? | 74 | 26 |
| 3) I enjoyed learning through this application; I will continue studying through this application? | 75 | 25 |

In addition, the present study mainly focused on the use of learning styles in providing a personalized learning content, while some other factors, such as the knowledge levels of the students, the difficulty levels of the learning materials and compensation type of adaption, were not considered.

Consequently, there are several areas in which we can extend this study. Firstly, we would like to explore the possibility of using artificial intelligence techniques to identify student learning style based on their interactions with the system rather than getting them to answer a set of questionnaire. Secondly, we would like to explore the idea of integrating different learning styles to help learners learn more effectively in a wider range of educational experiences. Finally, more services should be integrated in system: More pedagogical activities should be explored and integrated into system.

REFERENCES

- Akbulut, Y., & Cardak, C. S. (2012). Adaptive educational hypermedia accommodating learning styles: A content analysis of publications from 2000 to 2011. *Computers & Education*, 58(2), 835–842. doi:10.1016/j.compedu.2011.10.008
- Anthony, P., Joseph, N. E., & Ligadu, C. (2013). Learning How to Program in C Using Adaptive Hypermedia System. *International Journal of Information and Education Technology*, 3(2), 151–155. doi:10.7763/IJJET.2013.V3.254
- Bajraktarevic, N., Hall, W., & Fullick, P. (2003, August 26-30). ILASH: Incorporating learning strategies in hypermedia. *Proceedings of the Fourteenth Conference on Hypertext and Hypermedia*, Nottingham, UK.
- Brown, E., Brailsford, T., Fisher, T., & Moore, A. (2009). evaluating learning style personalization in adaptive systems: Quantitative methods and approaches. *IEEE Trans. Learn. Technol.*, 2(1), 10–22. doi:10.1109/TLT.2009.11
- Brown, E., Cristea, A., Stewart, C., & Brailsford, T. (2005). Patterns in authoring of adaptive educational hypermedia: A taxonomy of learning styles. *Journal of Educational Technology & Society*, 8(3), 77–90.
- Brown, E., Fisher, T., & Brailsford, T. (2007). Real users, real results: examining the limitations of learning styles within AEH. *Proceedings of the eighteenth Conference on Hypertext and Hypermedia* (pp. 57-66). doi:10.1145/1286240.1286261
- Brown, E., Stewart, C., & Brailsford, T. (2006). Adapting for visual and verbal learning styles in AEH. *Proceedings of the sixth IEEE international conference on advanced learning technologies (ICALT'06)* Kerkrade, The Netherlands (pp. 1145–1147). doi:10.1109/ICALT.2006.1652665
- Brusilovsky, P. (1996). Methods and techniques of adaptive hypermedia. *User Modeling and User-Adapted Interaction*, 6(2–3), 87–129. doi:10.1007/BF00143964
- Brusilovsky, P. (2001). Adaptive hypermedia. *User modelling and user adapted interaction*, 11(1/2), 87-110.
- Cabada, R. Z., Barrón Estrada, M. L., & Reyes García, C. A. (2011). EDUCA: A web 2.0 authoring tool for developing adaptive and intelligent tutoring systems using a Kohonen network. *Expert Systems with Applications*, 38(8), 9522–9529. doi:10.1016/j.eswa.2011.01.145
- Coffield, F., Moseley, D., Hall, E., & Ecclestone, K. (2004). *Learning styles and pedagogy in post-16 learning. A systematic and critical review*. UK: Learning and Skills Research Centre.
- De Bra. (2000). Pros and cons of adaptive hypermedia in web based education, *Cyber Psy. Behav*, 3(1), 71–77.
- Dunn, R., & Dunn, K. (1974). Learning style as a criterion for placement in alternative programs. *Phi Delta Kappan*, 56(4), 275–278.
- Eltigani, Y., Mustafa, M., & Sharif, M. S. (2011). An approach to adaptive Elearning hypemedia system based on learning styles (AEHS-LS): Implementation and evaluation. *International Journal of Library and Information Science*, 3(1), 15–28.
- Felder, R. M., & Silverman, L. K. (1988). Learning and teaching styles in engineering education. *Engineering Education*, 78 (7).
- Honey, P., & Mumford, A. (1982). *The manual of learning styles*. Maidenhead: Peter Honey.
- Honey, P., & Mumford, A. (2006). *The Learning Styles Questionnaire, 80-item version*. Maidenhead, U.K.: Peter Honey Publications.
- Hwang, G.-J., Sung, H.-Y., Hung, C.-M., & Huang, I. (2013). A Learning Style Perspective to Investigate the Necessity of Developing Adaptive Learning Systems. *Journal of Educational Technology & Society*, 16(2), 188–197.
- IMS MD. (2008). Retrieved from <http://www.imsglobal.org/metadata/index.html>
- Keefe, J. W. (1987). *Learning styles: Theory and practice*. Reston, VA: National Association of Secondary School Principals.
- Kolb, D. A. (1984). *Experiential learning: Experience as the source of learning and development*. Englewood Cliffs, NJ: Prentice Hall.

Lee, J., & Park, O. (2008). Adaptive instructional systems. In J. M. Spector, M. D. Merrill, J. v. Merriënboer, & M. P. Driscoll (Eds.), *Handbook of research on educational communications and technology* (3rd ed., pp. 469–484). New York: Taylor Francis.

Mampadi, F., Chen, S. Y., Ghinea, G., & Chen, M.-P. (2011). Design of adaptive hypermedia learning systems: A cognitive style approach. *Computers & Education*, 56(4), 1003–1011. doi:10.1016/j.compedu.2010.11.018

Manochehr, N. (2006). The influence of learning styles on learners in elearning environments: An empirical study. *Computers in Higher Education Economics Review*, 18(1), 10–14.

Papanikolaou, K. A., Grigoriadou, M., Kornilakis, H., & Magoulas, G. D. (2003). Personalising the interaction in a web-based educational hypermedia system: The case of INSPIRE. *User Modeling and User-Adapted Interaction*, 13(3), 213–267. doi:10.1023/A:1024746731130

Paredes, P., & Rodriguez, P. (2002). Considering learning styles in adaptive web-based education, *Proceedings of the sixth World Multi-conference on Systemics, Cybernetics and Informatics*, Orlando, FL. (Vol. 2, pp. 481–485).

Pask, G. (1976). Styles and strategies of learning. *The British Journal of Educational Psychology*, 46(2), 128–148. doi:10.1111/j.2044-8279.1976.tb02305.x

Popescu, E. (2008). An Artificial Intelligence Course Used to Investigate Students' Learning Style. *Proc. of ICWL '08, LNCS* (Vol. 5145, pp. 122 – 131).

Popescu, E. (2010). Adaptation provisioning with respect to learning styles in a web-based educational system: An experimental study. *Journal of Computer Assisted Learning*, 26(4), 243–257. doi:10.1111/j.1365-2729.2010.00364.x

Popescu, E., Trigano, P., & Badica, C. (2007). Adaptive educational hypermedia systems: A focus on learning styles. *Proceedings of the International Conference on Computer as a Tool (EUROCON)*, Warsaw, Poland. doi:10.1109/EURCON.2007.4400580

Sangineto, E., Capuano, N., Gaeta, M., & Micarelli, A. (2008). Adaptive course generation through learning styles representation. *Universal Access in the Information Society*, 7(1), 1–23. doi:10.1007/s10209-007-0101-0

Schiaffino, S., Garcia, P., & Amandi, A. (2008). eTeacher: Providing personalized assistance to e-learning students. *Computers & Education*, 51(4), 1744–1754. doi:10.1016/j.compedu.2008.05.008

Siadaty, M., & Taghiyareh, F. (2007). PALS2: pedagogically adaptive learning system based on learning styles. *Proceedings of the seventh IEEE international conference on advanced learning technologies (ICALT 2007)*, Niigata, Japan (pp. 616–618). doi:10.1109/ICALT.2007.198

Stash, N., Cristea, A., & De Bra, P. (2006). Adaptation to learning styles in e-learning: approach evaluation. In T. Reeves, & S. Yamashita (Eds.), *Proceedings of world conference on e-learning in corporate, government, healthcare, and higher education*, Chesapeake, VA, USA (pp. 284–291). AACE.

Stash, N., & De Bra, P. (2004). Incorporating cognitive styles in AHA! (The Adaptive Hypermedia Architecture). *Proceedings of the International 28 Int. J.Lib. Inf. Sci. Conference Web-Based Education (IASTED)*, Innsbruck, Austria (pp. 378–383).

Trantafillou, E., Pomportsis, A., & Georgiadou, E. (2002). AES-CS: adaptive educational system based on cognitive styles. *Proceedings of the Workshop on Adaptive Systems for Web-based Education, Held in Conjunction with AH 2002*, Malaga, Spain.

Triantafillou, E., Pomportsis, A., & Demetriadis, S. (2003). The design and the formative evaluation of an adaptive educational system based on cognitive styles. *Computers & Education*, 41(1), 87–103. doi:10.1016/S0360-1315(03)00031-9

Wolf, C. (2007). *Construction of an adaptive e-learning environment to address learning styles and an investigation of the effect of media choice* [Unpublished Doctoral Dissertation]. RMIT University, Melbourne, Australia.

Yang, T.-C., Hwang, G.-J., & Yang, S. J.-H. (2013). Development of an adaptive learning system with multiple perspectives based on students' learning styles and cognitive styles. *Journal of Educational Technology & Society*, 16(4), 185–200.

Samia Drissi is currently a PhD student in Computer Science at the Badji Mokhtar-Annaba University, Algeria. Also, she is a Senior Researcher at LiM Laboratory, University of Souk-Ahras, Algeria. She works in e-learning research field since 2006. Her PhD research is the learning style-based adaptive educational systems. Her current research interests include learning styles, adaptive hypermedia systems, learning management systems and learning achievements.

Abdelkrim Amirat received his PhD in Computer Science in 2007, and Habilitation in 2010. Currently he is an Associate Professor of Computer Science at the University of Souk-Ahras, Algeria. He is the Director of Mathematics and Computer Science Laboratory and the Chief of the Software Architecture Modelling Team. His main research concern is software architectures and their evolution, modelling and metamodelling. He worked on several national projects in software engineering. He has published several refereed journal and conference papers in the fields of software architecture, component-based, and object oriented modelling. He has served on Program Committees of several international journals, conferences and workshops.