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Adaptation with Four Dimensional Personalization Criteria Based on Felder Silverman Model

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ABSTRACT

In the past decades, various systems have been proposed to provide students with a better learning environment by taking personal factors into account. Learning styles have been one of the widely adopted factors in the previous studies as a reference for adapting learning content or organizing the content. However, very few researchers give an idea of matching e-media with appropriate teaching and learning styles and very few studies give an idea of which appropriate combinations of electronic media and learning styles are more effective than other. In this paper, the authors aim to prototype an AFDPC-FS system (Adaptation with Four Dimensional Personalization Criteria based on Felder Silverman model). Their system presents a general framework for combining and adapting teaching strategies, learning styles and electronic media according to Felder-Silverman's learning style model. An experiment was designed to explore the effect of adaptation to different learning styles when learning materials were matched with learning styles. In particular it was set up to see whether there are significant differences in learning achievement and cognitive load between two groups, an experimental group who studied with learning style-fit version and a control group who studied with non-fit version of the system without adaptation to learning styles. The experimental results showed that the proposed system could improve the learning achievements of the students. Moreover, it was found that the students' cognitive load was significantly decreased.

KEYWORDS

Cognitive Load, Learning Achievement, Learning Strategies, Learning Style, Personalized Learning

INTRODUCTION

The rapid advancement of computer and network technologies has attracted researchers to develop tools and strategies for conducting computer-assisted learning activities (Hwang, Wu, & Chen, 2012; Tsai, 2004). With these new technologies, learning content becomes rich and diverse owing to the use of hypermedia and multimedia presentations (Yang, Hwang & Yang, 2013).

Web-based adaptive e-learning hypermedia systems are suitable for providing personalized learning supports or guidance by identifying the personal characteristics of students and adapting the presentation styles or learning paths accordingly (Tseng, Chu, Hwang, & Tsai, 2008).

In the past decade, various personalization techniques have been proposed for developing adaptive e-learning hypermedia systems, and have revealed the benefit of such an approach (Mampadi, Chen, Ghinea, & Chen, 2011; Nielsen, Heffernan, Lin, & Yu, 2010; Wells & McCrory, 2011). In this respect, according to (Al-Azawei & Lundqvist, 2015; Hwang, Sung, Hung, & Huang, 2013) many personalized

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or adaptive learning systems have been developed based on a range of students' personal information, such as their profiles (e.g., gender, age, knowledge level, and background data), learning portfolios, and preferences (Chen, 2008; Wang & Liao, 2011; Wang & Wu, 2011). Recently, researchers have largely focused on learning styles due to several reasons. According to literature, learning styles have widely been used to avoid a 'one-size-fits-all' teaching approach (Akbulut & Cardak, 2012; Al-Azawei & Badii, 2014; Dorça, Lima, Fernandes, & Lopes, 2013; Felder& Brent, 2005). Learning style is a student characteristic indicating how a student learns and likes to learn (Keefe, 1991). For example, some learners prefer graphical representations and remember best what they see, others prefer audio materials and remember best what they hear, while others prefer text and remember best what they read. There are students who like to be presented first with the definitions followed by examples, while others prefer abstract concepts to be first illustrated by a concrete, practical example. (Popescu, 2010).

There are many studies on the effectiveness of combining multimedia and hypermedia with learning styles in educational systems (Najjar, 1996) (Liao, 1999). They attempt to associate specific e-media characteristics to different categories of learners and propose instruments and methods for assessing learning style (Riding & Rayner, 1998). Most of these studies based on Felder-Silverman learning style model (FSLSM) (Felder and Silverman, 1988). Examples of such systems include CS383 (Carver et al., 1999), TANGOW (Paredes and Rodriguez, 2004) and PHP Programming Course (Hong & Kinshuk 2004).

On the other hand, Learning strategies are the strategies used to remember, learn and use information. Consequently, Teaching strategies (TS) are the elements given to the students by the teachers to facilitate a deeper understanding of the information. The emphasis relies on the design, programming, elaboration and accomplishment of the learning content. Teaching strategies must be designed in a way that students are encouraged to observe, analyze, express an opinion, create a hypothesis, look for a solution and discover knowledge by themselves (Franzoni & Assar, 2009). In this regard, some of the previous studies worth mentioning are for example those of Dunn (1988), who insists on the importance of teaching the students by using methods that adapt to their conceptual preferences. Or Cabrero (2006), who also points out how the applied teaching strategies will take effect on the teaching quality, not only from an individual point of view, but also on the collaboration of the group as a whole.

However, very few researchers give an idea of matching e-media with appropriate teaching and learning styles and very few studies give an idea of which appropriate combinations of electronic media and learning styles are more effective than other (Franzoni & Assar, 2009). To cope with this problem, in this paper, we aim to prototype an AFDPC-FS system (Adaptation with Four Dimensional Personalization Criteria based on Felder Silverman model). Our system presents a general framework for combining and adapting teaching strategies, learning styles and electronic media According to Felder-Silverman's learning style model. More specifically, this paper focuses on the proposal for an adaptive taxonomy that will be used to release the fourth levels of adaptation: content level adaptation, link level adaptation, presentation level adaptation and collaboration level adaptation of an educational hypermedia, while based on the four dimensions of Felder-Silverman's learning style model.

LITERATURE REVIEW

Learning Style-Based Adaptive Educational Systems

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. There are several different learning style models including Honey and Mumford (1982), Kolb (1984), and Felder and Silverman (1988). Among those learning style models, the Felder–Silverman learning style (FSLSM) has been widely adopted and has been validated by various studies (Mampadi, Chen, Ghinea, & Chen, 2011; Ackbulut, 2012; Hwang, Sung, Hung, & Huang, 2013).

In the past decade, several studies have attempted to develop adaptive learning systems based on Felder-Silverman model. For example, CS383 (Carver et al., 1999) is based on 3 constructs of the FSLSM (sensing/intuitive, visual/verbal, sequential/global). For each category of resources (i.e., hypertext, audio files, graphic files, digital movies, instructor slideshows, lesson objectives, note-taking guides, quizzes, etc.), the teacher has to mention its suitability (support) for each learning style. TANGOW (Paredes and Rodriguez, 2004) is another system which is based on two dimensions of FSLSM: sensing/intuitive and sequential/global. In CS383 and TANGOW systems, the adaptation is done at the presentation level by means of the sorting fragments technique (according to the suitability for each particular learning style). Another adaptation technique is to customize the system's interface according to students' learning style as used in (Cha, Kim, Lee, & Yoon, 2006). The adaptation criterion is represented by the Felder-Silverman learning style model. The interface is adaptively customized: it contains 3 pairs of widget placeholders (text/image, audio/video, Q&A board/Bulletin Board), each pair consisting of a primary and a secondary information area. The space allocated on the screen for each widget varies according to the student's FSLSM learning style: e.g., for a visual learner the image data widget is located in the primary information area, which is larger than the text data widget; the two widgets are swapped in case of a verbal learner. Similarly, the Q&A Board and Bulletin Board are swapped in case of the active versus reflective learners.

Most of the systems shown above evaluate and adapt to the chosen learning styles dimensions of FSLSM. One disadvantage of these systems is that electronic media is limited to graphics, hypertext, audio and video, and that it doesn't integrate teaching strategies.

Furthermore, an electronic media can be used in different ways to implement different teaching strategies which can be matched with different learning styles. For example, (Franzoni & Assar, 2009) describe the design of a personalized teaching method using Felder and Silverman's learning styles and which is combined with the selection of the appropriate teaching strategy and the appropriate electronic media. As mentioned in (Franzoni & Assar, 2009), student with a sensitive style prefer practical content and methods that allow the solution of problems. When selecting the appropriate strategies, these must give priority to such practical work (learning based on problems, presentation and question and answer method). Electronic media, in turn, should contribute to these priorities, animations, simulation and forums (among others), are examples of media that allow the implementation of pragmatic solutions that can also be based on problems.

Later, Yang, Hwang and Yang (2013) developed AMDPC an adaptive learning system by using both learning styles and cognitive styles to adapt the user interface and learning content for individual students. AMDPC consists of the learning content-generating module and the adaptive presentation module. The adaptive presentation module consists of two parts: the layout strategy based on the field dependent/independent cognitive style and the instructional strategy based on Felder -Silverman's learning style model. The learning content-generating module is used to extract contents from raw materials and generate chunks of information for composing personalized learning materials based on the presentation layout. In AMDPC, each subject unit contains a set of components, such as the ID of the unit, texts, photos, etc. The components of a subject unit are classified into six categories (concept unit, text components example component, figure component and fundamental component).

To understand the interaction between learners' cognitive system and the given learning environment, the cognitive load theory (CLT) has become an acknowledged and broadly applied theory for instruction and learning (Van Merriënboer & Sweller, 2005; Schnotz & Kürschner, 2007; Yang, Hwang, & Yang, 2013). Thus, Cognitive load is defined as a multidimensional construct representing the load that a particular task imposes on the performer (Paas & van Merrienboer, 1994). It can be assessed by measuring mental load, mental effort (Sweller, van Merriënboer, & Paas 1998; Paas, Tuovinen, Tabbers, & Gerven, 2003; Yang, Hwang, & Yang, 2013; Krell, 2015). According to (Yang, Hwang, & Yang, 2013) Mental effort is related to the strategies used in the learning activities, in contrast mental load refers to the interactions between the learning tasks, subject characteristics and subject materials, which are highly related to the complexity of the learning content that the students need to face (Hwang & Chang, 2011).

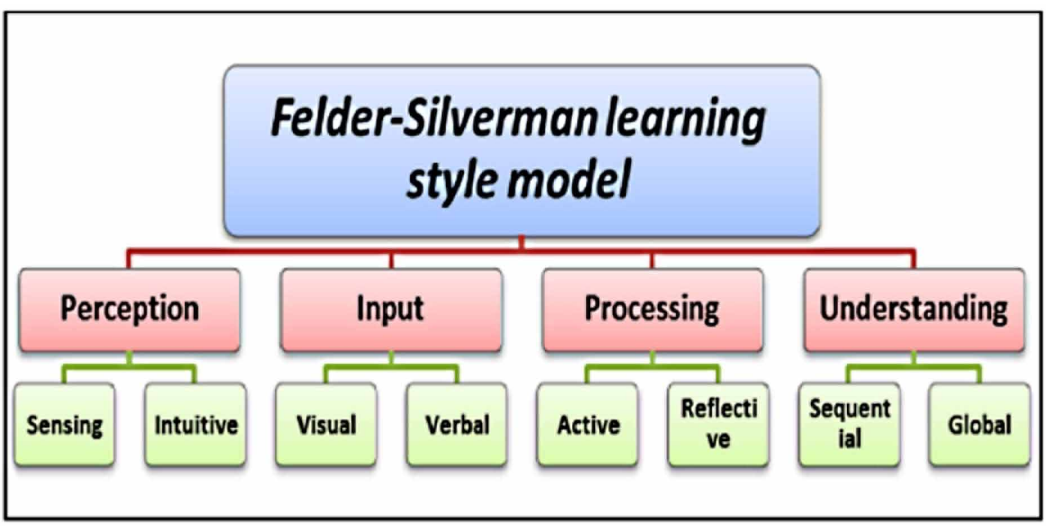
However, few experimental studies were conducted to investigate the effectiveness of matching learning materials to user's learning style by integrating the cognitive load theory. Consequently, to overcome this problem, in this research we will implement and evaluate a new adaptive educational hypermedia system based on Felder Silverman learning style model AFDPC-FS by assessing learners' learning achievement, learners' mental effort and learners' mental load. Our choice of this model is justified in the next sub section.

Felder Silverman's Model

In this research, we are focusing on the Felder-Silverman learning style model (FSLSM) because the (FSLSM) was widely used, more specifically, in Technology Enhanced Learning (TEL) (Akbulut & Cardak, 2012; Al-Azawei & Badii, 2014; Graf, Viola, & Leo, 2007). More specifically, according to Carver, Howard, & Lane (1999), the Felder Model is most appropriate for hypermedia courseware.

FSLSM contains four dimensions when learner is characterized by a specific preference for each of these dimensions. Each dimension includes two variables as shown in Figure 1. As detailed in (Graf, 2007), the first dimension covers sensing versus intuitive learning. Learners who prefer a sensing learning style like to learn facts and concrete learning material. In contrast, intuitive learners prefer to learn abstract learning material, such as theories and their underlying meanings. They are more able to discover possibilities and relationships and tend to be more innovative and creative than sensing learners. The second, visual-verbal dimension differentiates learners who remember best and therefore prefer to learn from what they have seen (e.g., pictures, diagrams and flow-charts), and learners who get more out of textual representations, regardless of whether they are written or spoken. In the third dimension, the learners are rated between an active and a reflective way of processing information. Active learners tend to be more interested in communication with others and prefer to learn by working in groups. In contrast, reflective learners prefer to work alone or may be in a small group together with one good friend. Finally, the fourth dimension characterized learners according to their understanding. Sequential learners learn in small incremental steps and therefore have a linear learning progress. Whereas, global learners use a holistic thinking process and learn in large leaps.

Figure 1. Felder-Silverman learning style model



Cognitive Load and Instructional Design

Cognitive Load Theory (CLT) has become one of the fundamental theories used to describe the cognitive processes in learning with new technologies, such as multimedia environments or web-based instruction (Brünken, Plass, & Leutner, 2003; Mayer, 2001; Niegemann, 2001). Because it is a framework of instructional design principles based on the characteristics and relations between the structures that constitute human cognitive architecture, particularly working memory and long-term memory (Wong, Leahy, Marcus, & Sweller, 2012; Yang, Hwang, & Yang, 2013; Leppink & van Merriënboer, 2015).

Cognitive load can be broadly defined as an individual's cognitive capacity which is used to work on a task, to learn, or to solve a problem (Sweller, Ayres, & Kalyuga, 2011; Leppink & van Merriënboer, 2015). CLT has become relevant in educational research. For instance, cognitive load may significantly influence a learner's performance and therefore should be considered when developing instructional designs (Sweller, Van Merriënboer, & Paas, 1998).

According to (Brünken, Plass, & Leutner, 2003) The cognitive load caused by the structure and complexity of the material is called intrinsic cognitive load, that is, the amount of informational units a learner needs to hold in working memory to comprehend the information. Cognitive load imposed by the format and manner in which information is presented and by the working memory requirements of the instructional activities is referred to as extraneous cognitive load. Finally, the load induced by learners' efforts to process and comprehend the material is called germane cognitive load (Gerjets &Scheiter, 2003; Renkl & Atkinson, 2003).

Cognitive load can be assessed by measuring mental load, mental effort (Sweller, van Merriënboer, & Paas 1998; Paas, Tuovinen, Tabbers, & Gerven, 2003). According to (Yang, Hwang, & Yang, 2013), mental effort is related to the strategies used in the learning activities. In contrast, mental load refers to the interactions between the learning tasks, subject characteristics and subject materials, which are highly related to the complexity of the learning content that the students need to face (Hwang & Chang, 2011).

Consequently, in this study we will integrate the cognitive load theory in order to evaluate a new adaptive educational hypermedia system based on Felder Silverman learning style model by assessing learners' learning achievement, learners' mental effort and learners' mental load.

RESEARCH QUESTIONS

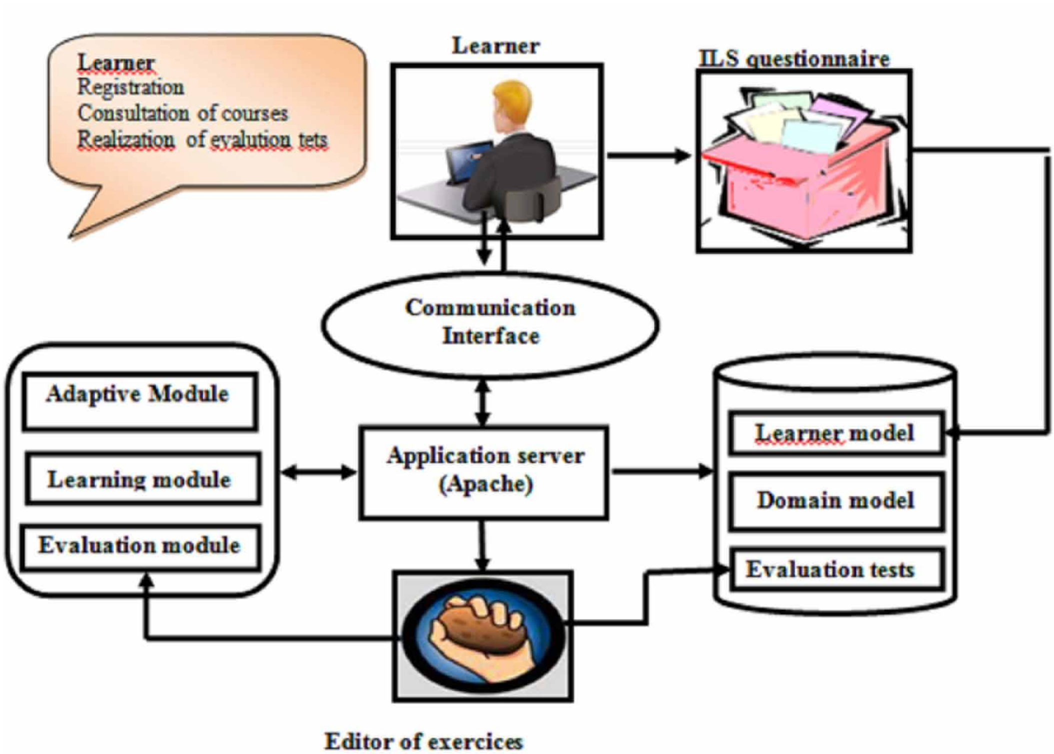
This study aims to prototype an AFDPC-FS system based on Felder-Silverman's learning style model, and compares it with a Conventional Hypermedia Learning System (CHLS) that does not exhibit any adaptation. It is expected that the proposed approach can benefit students in improving their learning achievement and reducing their cognitive load. Consequently, in this paper, we have reformulated the problem by investigating the following research questions:

1. Can the adaptive learning hypermedia system based on learning style show better achievement for students who learned with learning style-fit versions than those who learned with the conventional system with non-fit versions?
2. Does the adaptive learning hypermedia system based on learning style reduce students' cognitive load in comparison with the conventional system?

ARCHITECTURE OF THE PROPOSED SYSTEM

Our AFDPC-FS system is organized in the form of five basic components: the learner model, the domain model, the adaptive module, learning module and the evaluation module. These five components interacted to adapt different aspects of the instructional process. Figure 2 illustrates the system architecture.

Figure 2. Architecture of the proposed system AFDPC-FS



Learner Model

In AFDPC-FS, 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.

Phase 2: Selection of learning styles of learners is performed using the Index of Learning Style Questionnaire (ILQ), developed by Felder and Soloman (1997) which is used to categorize the students into four dimensions (Sensing/Intuitive, Sequential/Global, Visual/Verbal and Active/Reflective). The description of these dimensions is detailed in Table 1.

So in this phase, the learner must complete a questionnaire containing 44 questions (11 items per dimensions). Each learner has a personal preference for each dimension. These preferences are expressed with values between +11 to -11 per dimension, with steps +/-2. This range comes from the 11 questions that are posed for each dimension. For example, when answering a question, with an active preference, +1 is added to the value of the active/reflective dimension whereas an answer for a reflective preference decreases the value by 1. Therefore, each question is answered either with a value of +1 (answer a) or -1 (answer b). (Answer a) corresponds to the preference for the first pole of each dimension (active, sensing, visual, or sequential), (answer b) to the second pole of each dimension (reflective, intuitive, verbal, or global).

Table 1. Description of Felder Silverman dimensions

Learning Style	Description
Sensing	Prefer concrete facts, data and relation to real word around. Rather deal with facts, raw data and experiments, they're patient with details, but don't like complications.
Intuitive	Focus on ideas and possibilities. Prefer abstraction, theories and models. Rather deal with principles and theories, are easily bored when presented with details and tend to accept complications.
Sequential	Orderly, step by step and sequential. Follow a lineal reasoning process when solving problems and can work with a specific material once they've comprehended it partially or superficially.
Global	See everything as a whole. Take big intuitive leaps with the information, may have a difficulty when explaining how they got to a certain result, need an integral vision.
Visual	Easy for them to remember what they see: images, diagrams, time tables, films, etc.
Verbal	Remember what they've heard, read or said.
Active	Motivated, prefer trial-and-error. Enjoy discussion rather than learning independently. "learning by doing" to describe how active students learn. Learn by working in groups and handling stuff.
Reflective	Learn better when they can think and reflect about the information presented to them. Learn a good deal from independent work. Work better alone or with one more person at most. "Learning by thinking" could describe Reflective students.

Domain Model

In our research, the domain model is represented by three levels: course, chapter and finally learning objects. Learning objects represent any digital resources that can be reused to support learning (IMS MD, 2008). 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. 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.

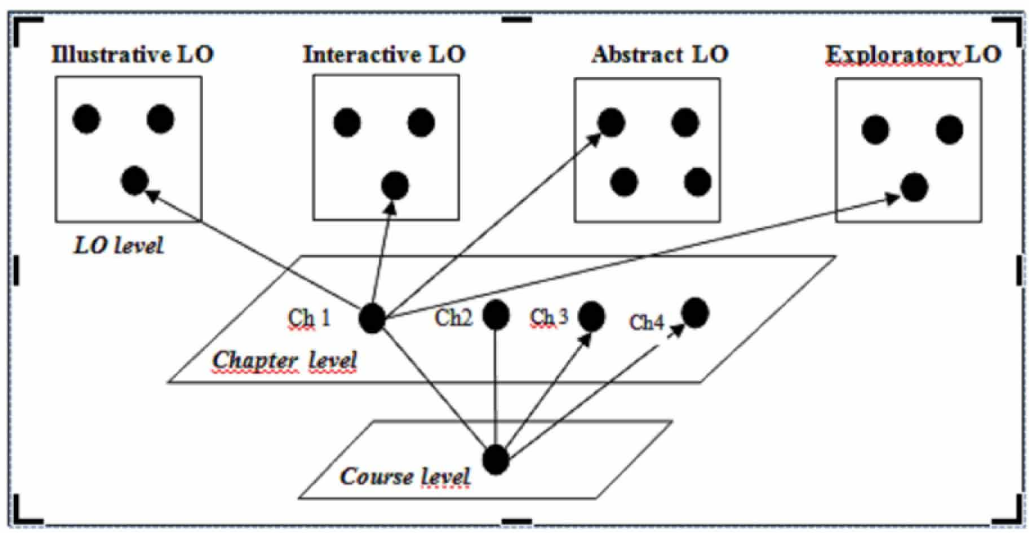
In order to make an association between this model of domain and the four dimension of the Felder Silverman model, we are going to use four types of learning objects as described in (Drissi & Amirat, 2016) to teach every concept of a given course. Then the conception of these learning objects was described in Figure 3 and adopted in the following way:

- Exploratory learning objects: allow describing in a concrete way some lived experiences, these exploratory learning objects help well teaching the exploration of a concept. 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), these illustrative learning objects allow the learner the reflection, the observation and the accumulation of data before emitting an opinion.
- Theoretical learning objects: reinforced by theoretical presentation. Then these theoretical presentations can be presented by definitions or theories.
- Interactive learning objects: (An interactive simulation, resolution of problem, exercise), they allow the learner the application and the try of the knowledge and the ideas.

Adaptive Module

The adaptive module aims to provide a personalized learning resource for students, especially learning content by suggesting personalized learning paths and adaptive layouts when we proposed an adaptive taxonomy that integrates learning strategies, learning styles and electronic media. This

Figure 3. Organization of domain model



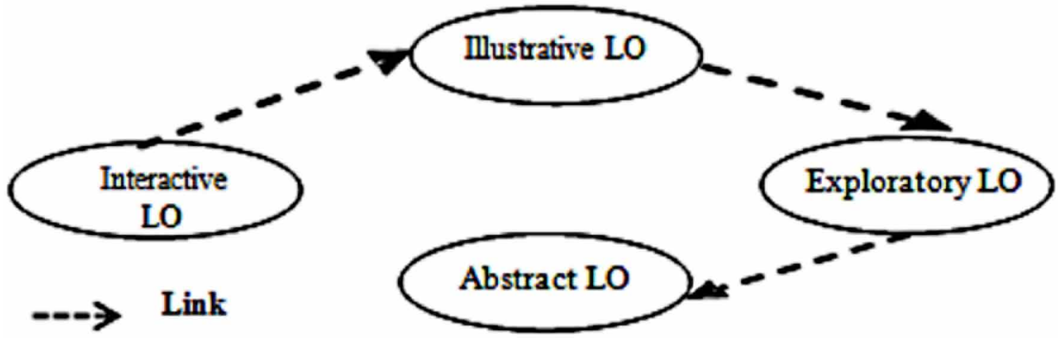
adaptive taxonomy focuses on a set of resources those summarized as navigation tool, collaboration and communication tool, overview tool and a set of learning objects. As mentioned above, the learning objects are structured into abstract learning objects, illustrative learning objects, exploratory learning objects and interactive learning objects. These learning objects are presented in the form of text, picture sound and animation. Furthermore, our adaptive taxonomy is adopted in order to release the fourth levels of adaptation: content level adaptation, link level adaptation, presentation level adaptation and collaboration level adaptation of an educational hypermedia course, while based on the four dimensions of Felder-Silverman's learning style model. To release the four levels of adaptation, our adaptive module consists of four sub-modules: the Adaptive Content Sub-Module (ACtSM), the Adaptive Navigation Sub-Module (ANSM), the Adaptive Presentation Sub-Module (APSM) and the Adaptive Collaboration Sub-Module (ACSM).

The Adaptive Content Sub-Module (ACtSM)

The ACtSM uses the " perception dimension " of Felder-Silverman's learning style model that rates students into groups (sensing / intuitive) to realize the content level adaptation. Based on individual student's ratings in processing dimension, the ACtSM adapts the instructional strategy to meet their needs. In, this work, we use two different strategies: practical strategy and abstract strategy.

- ***Practical strategy:*** this strategy is designed for sensitive learners. It begins with interactive learning objects displayed in full screen as mentioned in Figure 4. Interactive learning objects can be represented for example by an interactive simulation, a resolution of problem or an exercise. Followed by a first link to illustrative objects that can be presented by: an example, illustration, comparison, analogy or either against examples, and a second link to the exploratory learning objects that can be presented by the case studies or by the filmed experiences. And finally a link to abstract objects reinforced by theoretical presentation that can be presented by definitions or theories.

Figure 4. Practical strategy



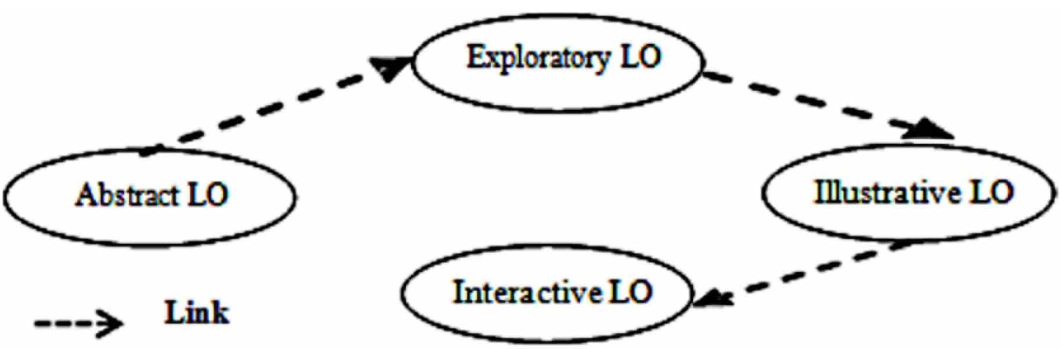
- ***Abstract strategy:*** this strategy is designed for intuitive learners. It begins with abstract learning objects displayed in full screen as mentioned in Figure 5. Abstract learning objects can be represented by definitions or theories. Followed by a first link to exploratory objects, and a second link to illustrative objects, and finally a link to interactive objects.

The Adaptive Navigation Sub-Module (ANSM)

The ANSM uses the "understanding dimension" of Felder-Silverman's learning style model that rates students into groups (Sequential / Global) to realize the navigation level adaptation. Thus, based on individual student's ratings in understanding dimension, the adaptive navigation support technology is mainly implemented by the ANSM through three types of adaptive hypermedia techniques, including direct guidance, link hiding and adaptive layout.

- ***Direct guidance:*** As described above in Table 1, the " understanding dimension " of Felder-Silverman's learning style model show that the global students see everything as a whole and like to have several things "on the go" at the same time. The global students take big intuitive leaps with the information, and have a difficulty when explaining how they got to a certain result. Thus, Global students adopt a comparatively exploratory strategy that requires no direct guidance that would restrict their "jumping around" approach. On the other hand, the Sequential students are orderly and follow a step-by-step logical progression, making sure to build solid

Figure 5. Abstract strategy



foundations for each next move. Hence, direct guidance using NEXT/PREVIOUS buttons was used for sequential students.

- ***Link hiding:*** Due to the fact that the Sequential students follow a lineal reasoning process, and prefer a linear navigation strategy to avoid their disorientation, the ANSM uses the "Serialist Version" provided users with restricted navigation choices. On the other hand, the ANSM uses a "Global Version" that riches links within the main body of the text. So, global students using "Global Version" are provided with freedom of navigation and can jump to different subject topics.
- ***Adaptive layout:*** Due to the fact that the global students have needs to see the big picture of the system, the ANSM proposes overview tool that helps them to get the overall picture of the content being presented. Exactly, the adaptive layouts were applied in the form of overview map and glossary that are used by global students to understand the content structure. While sequential students favored to use the alphabetical index, which can facilitate them to locate specific information.

The Adaptive Presentation Sub-Module (APSM)

APSM exploits the "Entry channel" dimension to adapt the presentation of courses using different media and different learning materials. So, Due to the fact that visual students remember best what they see, the APSM will provide them with more visual materials, such as diagrams, pictures, charts, graphs and demonstrations. On the other hand, verbal students prefer text description and get more out of written and spoken explanations. Consequently, APSM provide verbal students with more text and sound materials.

The Adaptive Collaboration Sub-Module (ACSM)

Finally, The ACSM uses the " Processing dimension " of Felder-Silverman's learning style model that rates students into groups (Active / Reflective) to realize the collaboration level adaptation. So, if the student's learning style is "active", the ACSM presents to this type the opportunity to participate in collaboration and communication tools such as forum and e-mail because active student tends to be more interested in communication with others and prefers to learn by working in groups where he/she can discuss about the learned material. However, reflective students can't participate to collaboration tools, because this type of students Works better alone.

In summary, Table 2 lists tools and learning objects structure used by our adaptive module that are beneficial for different type of Felder Silverman's learning style dimensions.

Learning Module

The learning module provides students with personalized learning content by suggesting personalized learning paths and adaptive layouts based on their four dimensions of Felder-Silverman's learning style model. Hypermedia in which we applied our approach is derived from "computer networks" course. Figure 6 shows a learning module for a student with "intuitive, sequential, verbal and reflective" learning style. In this case, a learning module provides this student with an abstract strategy that begins with abstract learning objects (definitions or theories). These definitions or theories are presented in the form of text. Also, a direct guidance using NEXT/PREVIOUS buttons was presented also for this student. While, Figure 7 is a learning module for another student with " intuitive, global, visual and active" learning style. As show in Figure 7, the learning module provides this student by a global version of interface that presents more information to help him/her to make a comprehensive survey of learning content. Specially, this interface contains a lot of visual learning objects. It includes a communication and collaboration tools because this type of student tends to be more interested in communication with others and prefers to learn by working in groups. Moreover, the user interface in Figure 6 (for sequential student) is much simpler than that in Figures 7 (for global student). More

Table 2. Adaptive taxonomy for Felder Silverman dimensions

Adaptation level	Tools	Perception dimension		Understanding dimension		Entry chanel dimension		Processing dimension	
		Sensing	Intuitive	Sequential	Global	Verbal	Visual	Active	Reflective
Content adaptation level	Practical strategy	✓							
	Abstract strategy		✓						
Navigation adaptation level	Next/previous button			✓					
	Serialist version			✓					
	Global version				✓				
	Overview map and glossary				✓				
	Alphabetical index			✓					
Presentation adaptation level	diagrams						✓		
	Pictures						✓		
	charts						✓		
	graphs						✓		
	demonstrations						✓		
	text					✓			
	sound					✓			
Collaboration adaptation level	Forum							✓	
	e-mail							✓	

specifically, the user interface in Figure 7 contains a lot of links presented in the form of adaptive map in the left of the interface and an overview map in the right of the same user interface.

Evaluation Module

Evaluation module presents to the learners a set of evaluation tests in order to evaluate their knowledge in two levels the pre-test level and post-test level. This module provides learners different types of exercises including: multiple choice questions (MCQ) and matching questions.

In AFDPC-FS, 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. In our system, tow applications are used: JQuiz editor (multiple choice questions or MCQs) and JMatch (Editor of matching exercises).

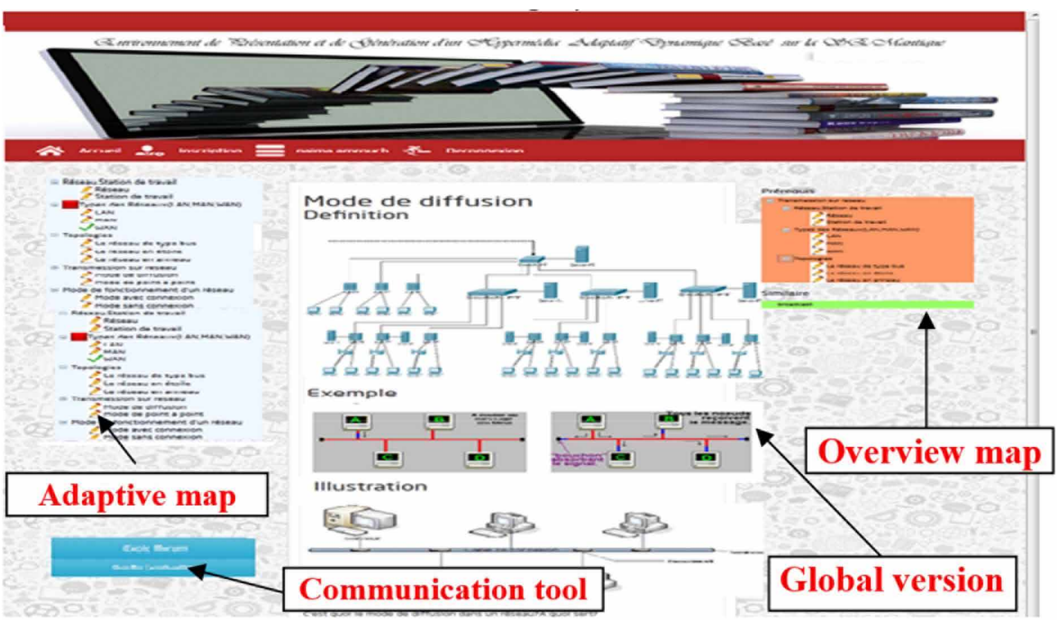
EXPERIMENT AND EVALUATION

The main objectives of this research are to answer the following questions that were defined in the research questions section: introducing learning styles in Adaptive E-learning Hypermedia Systems can firstly improve learner's achievements and performance and secondly reduce students' cognitive load?

In order to answer the previous questions, using our AFDPC-FS system, an experiment for a period of three months 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 styles. In particular it was set up to see whether there are significant differences in learning achievement and cognitive load between two groups, an experimental group who studied with learning style-fit version and a control group who studied with another version (non-fit version) of the system without adaptation to learning styles. The non-fit version contains the same concepts of " computer networks " course those are presented in the learning style-fit version. These concepts of non-fit version are presented as those of the learning style-fit version in different media but in a non-linear way.

Figure 6. Learning module for a student with "intuitive, sequential, verbal and reflective" learning style

Figure 7. Learning module for a student with "intuitive, global, visual, active " learning style



Participants

Before discussing our online experiment, forty-six (46) students were randomly selected to take part in this experiment. All were third year students at the College of Sciences and Technology at Souk Ahras University (Algeria). The participants were randomly divided into a control group (n = 23) and an experimental group (n = 23).

Experimental Procedures

In the first stage, the students were instructed in the basic knowledge of “ computer networks “ course. This stage was conducted twice a week for four weeks; each session lasted for 30 minutes. 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 AFDPC-FS system; that is, they were provided with an adaptive version (learning style-fit version) by taking both their learning styles into account. On the other hand, the students in the control group learned with another version of the system (non-fit version) without adaptation to learning styles. After conducting the learning activity, the students took a post-test and answered a post-questionnaire. This stage took 120 minutes.

And finally in the third stage, students in both groups were provided with another questionnaire for measuring their cognitive load. This stage took 20 minutes.

Research Instruments

Four testing instruments were used in this experiment. The first was the Index of Learning Style Questionnaire (ILQ), developed by Felder and Soloman (1997) which is used to categorize the students into four dimensions (Sensing/Intuitive, Sequential/Global, Visual/ Verbal and Active/ Reflective). The second was a pre-test questionnaire and a post-test questionnaire conducted to assess participant’s levels of knowledge of the subject domain both before and after using the system. The pre-test was composed of 10 true-or-false items, 10 multiple-choice items and 10 matching items with a full score of 100. The post-test questionnaire consisted of 13 multiple-choice items and 17 matching items with a full score of 100. Both the pre-test and post-test were designed by the teacher who taught the Computer Networking course to the two groups of students. The pre-test and post-test were evaluated by two science educators for expert validity. Overall, the reliabilities of the pre-test and post-test scores were acceptable. The alpha coefficient of the pre-test scores was 0.72 while the alpha coefficient for post test scores was 0.84. The third was the cognitive load measure to assessing mental load that asks to indicate the complexity of tasks, and mental effort that focuses on personal effort (Krell, 2015). In this study, we adopted the instrument used by Nehring, Nowak, Upmeier zu Belzen, & Tiemann (2012) consisting of 6 items representing mental load and 6 items representing mental effort. For each item, a 7-point rating scale was provided. The Cronbach’s alpha values of the two dimensions mental load and mental effort were 0.82 and 0.79, respectively.

RESULTS AND DISCUSSION

Results Specific to Learning Achievement

The independent t-test was used first in order to determine whether the control group and experimental group had the same prior knowledge on studied domain. As can be seen in Table 3, 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.

The first hypothesis of this research is:

Table 3. 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
52.02	14.20	53.64	12.29	1.37	44	0.178

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

Null hypothesis H0: the use of the learning styles as adaptivity in Adaptive E-learning Hypermedia Systems cannot improve student's achievement and performance.

The independent 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 ($t = -2.90$, $df = 44$, $p = 0.006 < 0.05$).

Table 4 shows the comparison results, the difference was statically significant; therefore the null hypothesis H0 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".

Our findings agreed with previous study from Hwang, Sung, Hung and Huang (2013) that 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 than those who learned with a conventional e-learning system. Therefore, our results support previous research (Popescu, 2008, 2010), (Eltigani, Mustafa, & Sharif, 2011), (Anthony, Joseph, & Ligadu, 2013), (Yang, Hwang, & Yang, 2013) and (Authors, 2016), 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, Stewart, & Brailsford, 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.

Results Specific to Cognitive Load

The second hypothesis of this research is:

Null hypothesis H0: the use of the learning styles as adaptivity in Adaptive E-learning Hypermedia Systems cannot reduce students' cognitive load in comparison with the conventional system.

In order to verify this hypothesis, we calculated the difference of the cognitive load results of the students. For doing this, we must assess the mental effort and mental load.

Table 5 shows the independent t-test result of the mental effort ratings of the control group and the experimental group. There is a very significant difference between the two groups in terms of

Table 4. 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
58.52	11.22	67.28	08.69	-2.90	44	0.006*

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

Table 5. Independent t-test of the mental effort level of the experimental group and the control group according to post-test result

Control group		Experimental group		Independent t-test		
Mean	SD	Mean	SD	t	df	P-value
04.70	1.78	03.05	01.18	03.63	44	0.0007**

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

mental effort. Exactly, the experimental group showed significantly lower mental effort than the control group with (($t = 3.63$, $df = 44$, $p = 0.0007 < < 0.05$).

According to results shown in Table 6, there is a significant difference between the two groups in terms of mental load. Results show that the experimental group showed significantly lower mental load than the control group with ($t = -2.071$ and $p = 0.044 < .05$).

Consequently, Table 5 and Table 6 show the comparison results of the cognitive load levels of the control group and experimental group, the differences were statically significant; therefore the null hypothesis H0 of the second hypothesis of this research 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 can reduce students' cognitive load by decreasing the mental load and mental effort.

Based on the Cognitive Load Theory (CLT), mental load refers to the interactions between the learning tasks, learning content, and the characteristics of the content (e.g., difficulty level), it is highly related to the difficulty level of the content presented to the students and the students' prior knowledge for comprehending the content. Whereas, mental effort is related to the learning strategies used in the learning activities (Verhoeven, Schnotz, & Paas, 2009). So according to our experimental results, we found that students' mental load and student's mental effort was significantly decreased and more specifically in the term of mental effort ($p = 0.0007 < < 0.05$). This reduction of cognitive load justifies that our proposed approach is promising and encourages the idea of combining teaching strategies, learning styles and electronic media in adaptive elearning hypermedia systems. Therefore, our results in term of mental load support previous research performed by (Yang, Hwang, & Yang, 2013), which found that during the adaptation of course based on learners learning styles, experimental group showed significantly lower mental load than the control group with ($t = 1.46$ and $p < .05$). Contrariwise, our results in term of mental effort are inconsistent with those published in the same research which proves that learning style based on adaptive e-learning hypermedia systems did not have a significant difference between the two groups in terms of mental effort.

CONCLUSION

Adaptive Learning seeks to achieve the same level of flexibility and real-time support found in the relationship between an engaged learner and an active learning mentor. In Adaptive Learning, the learner can dynamically adjust the form and/or content of the instruction to personalize the learning

Table 6. Independent t-test of the mental load level of the experimental group and the control group according to post-test result

Control group		Experimental group		Independent t-test		
Mean	SD	Mean	SD	t	df	P-value
05.96	1.70	05.09	01.02	-2.071	44	0.044*

*Significant difference, SD: standard deviation, t: t-test value, df: degree of freedom, P-value: probability value experience. Importantly, the learner can tailor the event to focus on unique learning needs and, also, the learner's questions are addressed specifically and in real-time. Consequently, Adaptive learning has been identified as being an important and challenging issue of computers in education. Through this research, we rappelled that in the past decades, various systems have been proposed to provide students with a better learning environment by taking personal factors into account. Learning styles have been one of the widely adopted factors in these studies as a reference for adapting learning content or organizing the content. However, very few studies give an idea of matching e-media and learning strategies with appropriate learning styles and very few studies give an idea of which appropriate combinations of electronic media and learning styles are more effective than other. Moreover, in most systems, only one adaptation level or two adaptation levels is/ are taken. In this paper, we have presented a general framework for combining and adapting teaching strategies, learning styles and electronic media according to Felder-Silverman's learning style model. More specifically, in this paper, we have proposed an adaptive taxonomy used to release the fourth levels of adaptation by using firstly, the " perception dimension " of Felder-Silverman' model to adapt learning content. Secondly, the " understanding dimension " to realize the navigation level adaptation. Thirdly, the " entry channel dimension " to realize the presentation level adaptation. And finally, the " processing dimension " to realize the collaboration level adaptation. The experimental results showed that the proposed system could improve the learning achievements of the students.

In the other hand, cognitive load theory has become one of the fundamental theories used to describe the cognitive processes in learning with new technologies, such as multimedia environments or web-based instruction (Mayer, 2001; Niegemann, 2001). Because it provides a theory-based approach to the prediction of the effectiveness of multimedia- and web-based learning, CLT is increasingly used to inform the instructional design of such learning environments (Brünken & Leutner, 2001). As mentioned in this paper, cognitive load can be assessed by measuring mental load and mental effort when mental effort is related to the strategies used in the learning activities. Whereas, mental load is highly related to the difficulty level of the content presented to the students and the students' prior knowledge for comprehending the content (Verhoeven, Schnotz, & Paas, 2009). In this study, we rappelled that the learning content presented to both group of students was not identical where the navigation, presentation and collaboration levels were adapted to the experimental group based on its learning styles. Consequently, in this research, it was found that the students' mental load and the student's mental efforts were significantly decreased.

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. 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.

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