BVG Trust

J. Sci. Trans. Environ. Technov., 2016, 10(1) :43-48

Scientific Transactions in Environment and Technovation

Development of adaptive learning system based on the field dependent/ independent cognitive style model for improving learning performance

A.Saranya and V.Geetha*

https://doi.org/10.56343/STET.116.010.001.010
http://stetjournals.com

PG and Research Department of Computer Science, Sengamala Thayaar Educational Trust Women's college, Sundarakkottai, Mannargudi-614016, Tamilnadu, India.

Abstract

In this proposed e-learning model an adaptive learning system is developed 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 was 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 of students revealed significantly better learning achievements than the control group of students, implying that the proposed approach is able to assist the students in improving their learning performance.

Keywords: E-Learning, Adaptive learning system, Fielder-Silverman's Learning style, continuous Education, cognitive style model, etc.,

INTRODUCTION

Rapid advancement in computer and network technologies has attracted researchers to develop tools and strategies for conducting computer-assisted learning activities (Chen *et al*., 2012). The new emerging technologies have made the learning content becomes rich and diverse owing to the use of hypermedia and multimedia presentations. Researchers have indicated that 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 (Chiou *et al*., 2008). In the past decade, various personalization techniques were proposed for developing adaptive hypermedia learning systems, which proved such approaches are being useful and beneficial (Chen *et al*., 2011). (Papanikolaou, 2002) developed an adaptive learning system by taking student's knowledge levels as the main factor for adapting the learning content. Whereas Chiou *et al*. (2008) developed an adaptive learning system based on an object-oriented frame wok that composes personalized learning content by considering individuals' knowledge level and the difficulty level of the learning objects.

Although the knowledge level of the students and the difficulty level of the learning content are good factors for adapting presentation layouts and selecting appropriate learning content for individuals. The importance of taking personal preferences and learning habits into account has been highlighted (Chiou *et al*., 2008, 2010). Among those personal characteristics, learning styles, which represent the way by which the individuals perceive and process information, have been recognized as being the important factors related to the presentation of learning materials (Papanikolaou, 2003). On the other hand, cognitive styles have been recognized as the essential characteristic of individuals' cognitive process. In the past decade, researchers have tried to develop adaptive learning systems based on either learning styles or cognitive styles; nevertheless, seldom have both of them been taken into consideration, not to mention the other personalized factors (Chiou and Chen *et al*., 2011).

Researchers have indicated the importance of taking multiple personalization factors into account in order to deliver effective learning systems to individual students (Chiou *et al*., 2008). To cope with this problem, in this study, an adaptive learning system is developed by taking students' preferences and characteristics, including learning styles and cognitive styles, into consideration. Moreover, an experiment has been conducted to show the effectiveness of the proposed approach.

*Corresponding Author :
email: *stet.csdept@gmail.com*

RELATED WORK

Learning styles have been recognized as being an important factor for better understanding the model of learning and the learning dispositions/preferences of students (Filippidis and Tsoukalas, 2009). Individual's learning style has been defined as a consistent way of functioning that reflects the underlying causes of learning behaviour, it has been pointed out that learning style is a student characteristic indicating as to how a student learns and likes to learn. It has also been stated that learning style could be an instructional strategy informing the cognition, context and content of learning. (Bloom, 1956) indicated that learning styles are likely to influence the learning behaviour of the student, the teaching styles of the instructor and the interaction between them. (Coffield and Moseleyl 2004) further suggested that teachers and course designers pay attention to students' learning styles and design of teaching and learning interventions accordingly.

The student's knowledge level of a domain concept is usually affected by her/his knowledge level of other related domain concepts. This fact leads to the need to represent the knowledge dependency relations between the individual domain concepts of the domain knowledge. The representation of this kind of relations of the learning material's domain concepts is performed by Fuzzy Cognitive Maps (FCMs) FCM is a cognitive map within which the relations between the elements of a "mental landscape" (like concepts, events, and project resources) can be used to compute the "strength of impact" of these elements. They constitute a way to represent real-world dynamic systems, in a form that corresponds closely to the way by which humans perceive it.

There have been several learning style theories proposed by researchers, such as those proposed by(Felder and Silverman, 1988) Several previous studies have demonstrated the use of learning styles as one of the parameters for providing personalized learning guidance or contents (Papanikolaou, 2006; Chiou *et al*.,2008). Among various learning styles, the Felder–Silverman Learning Style Model (FSLSM) developed by (Felder and Soloman, 1997) has been recognized by many researchers as being a highly suitable model for developing adaptive learning systems (Lin, 2012). Carver *et al*. (1999) indicated that FSLSM could be the most appropriate measurement for developing hyper media course ware by taking the personal factors into account. Lin (2007) compared several learning style models, and suggested that FSLSM is the most appropriate model with respect to the application in e-learning systems. Hence in this study also FSLSM has been adopted as one of the factors for developing the adaptive learning system.

On the other hand, cognitive style has been recognized as the significant factor influencing student's information seeking and processing (Chen *et al*., 2008). It has also been identified as an important factor impacting the effectiveness of user interfaces and the navigation strategies of learning system (Chen *et al*., 2011).

Several studies have shown the effectiveness of considering cognitive styles in designing user interfaces for information seeking (Chen *et al*., 2008) and developing adaptive learning systems for providing personalized learning guidance (Chen *et al*., 2012). Among the various proposed cognitive styles, the field dependent (FD) and field independent (FI) styles proposed are the most frequently adopted. Several studies have reported the usefulness of FI/FD cognitive styles in determining the suitability of learning supports or learning system designs (Lin and Chiou *et al*., 2012). Thomson (1995) has also stated that FI/FD cognitive style is very suitable for personalized learning design since it reveals as to how well a learner is able to restructure information based on the use of salient cues and field arrangement. Chen *et al*. (2000) further indicated that the FD/FI cognitive style is highly related to hypermedia navigation and is very suitable for evaluating the applicability of websites to students. Therefore, in this study, FI/FD cognitive style is adopted as another factor for developing the adaptive learning system.

Cognitive load is defined as a multidimensional construct representing the load that a particular task imposes on the performer (Felder,1994). It can be assessed by measuring mental load, mental effort (Felder, 2003). Mental effort is related to the strategies used in the learning activities, whereas 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 (Chiou *et al*., 2011).

Most of the digital learning materials are developed with multimedia in order to respond to the reality. Chen (2004) proposed a cognitive theory of multimedia learning (CLML), which assumes the human process with pictorial and verbal materials via different sense channels (i.e., sight and hearing). Consequently, cognitive overloading could occur when learners receive redundant information, poorly structured information, or large amount of information in a sense channel.

Several studies have been conducted to develop adaptive learning systems based on learning styles or cognitive styles. For example, Chiou (2008) proposed an adaptive learning system for elementary school mathematics courses by considering student's learning styles and the difficulty of the learning content. Chen

(2011) developed a web-based learning environment by providing different user interfaces based on students' cognitive styles. Furthermore, Chiou and Chen (2011) developed an adaptive mobile learning system that guided individual students to learn garden based butterfly ecology on student's learning styles. However, few studies have considered multiple learning criteria, including learning styles, cognitive styles and knowledge level, for developing adaptive learning systems.

PROPOSED MODEL

In this study, an adaptive learning system is developed based on both cognitive styles and learning styles. It is expected that the proposed approach can benefit students in improving their learning achievement, reducing their cognitive load and promoting their learning motivation. Accordingly, the following research questions are investigated

1. Does the adaptive learning system developed based on both cognitive styles and learning styles benefit students more than the conventional learning style-based system in terms of learning achievements?

2. Can the learning system developed based on both cognitive styles and learning styles decrease student's cognitive load in comparisons with the conventional learning style-based system?

3. Does the learning system developed based on both cognitive styles and learning styles benefit students more than conventional learning style-based system in terms of learning motivations?

Learning content-generating module

The concept of the learning content-generating module, which is used to extract contents from raw materials and generate chunks of information for composing personalized learning materials based on the presentation lay out is presented in Figure 1. Each subject unit contains a set of components, such as ID of the unit, texts, photos, etc. The components of a subject unit are classified into the following five categories:

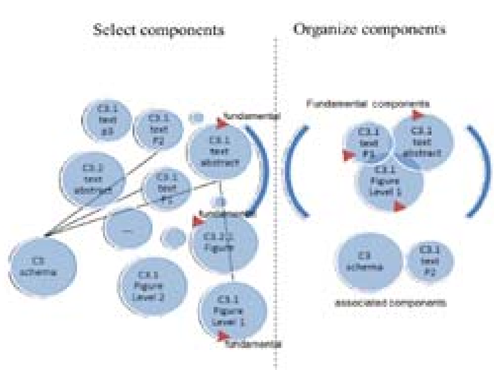

Fig. 1. The learning content generating module

• *Concept unit*: containing the title, concept ID, abstract and representative icon of the course unit.

• *Text components*: the text content of the course unit.

• *Example component*: the illustrative examples related to the course content.

• *Figure component:* the pictures, photos and figures related to the course unit.

• *Fundamental component*: Fundamental components contain the primary contents of a course, including the title of each learning unit or concept, and the corresponding texts, figures, examples and exercises.

After selecting the appropriate components (learning materials), LCGM organizes the selected components based on individual students' learning styles and cognitive styles. The organized learning content is then presented to individual students based on the presentation layout framework. Figure 2 shows this framework, which consists of the following areas

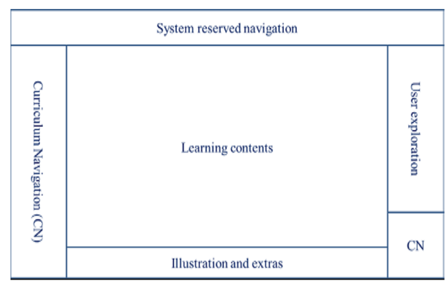

Fig. 2. The presentation layout framework of AMDPC

· *The system reservation area*: This area is reserved for the learning system to display the status or announcements about courses, students or the system.

· *The curriculum navigation area*: This area contains the information about the relationships between the course units, the outline of individual courses, and the suggested learning sequence.

• *The learning content area*: This area is located in the centre of the screen for presenting the learning materials organized by LCGM.

• *The supplementary material area*: This area is used to present supplementary learning materials to individual students based on their personalized learning needs.

• *The user exploration area*: In this area, three icons linked to three different versions of learning content are presented to enable flexible student control during the learning process.

• *The guided navigation area*: This area is allocated at the bottom-right corner of the screen. It is used to provide style-matching learning guidance or navigation functions for students with different learning styles or cognitive styles. For example, for the

FD students, "next stage" and "previous stage" buttons are provided to guide the students to learn the course materials in an appropriate sequence.

Adaptive content module

The ACM is related to content adjustment for students of different learning styles. The Index of Learning Style questionnaire (ILS), proposed by Felder and Solomon (1997) was embedded in the learning system for measuring the learning styles of the students. There are four dimensions of learning style (LS) in the Felder-Silverman learning style model

1. *Active/Reflective dimension*: *Active students* are active, motivated, prefer trial-and-error, and enjoy discussion rather than learning independently. We use the term "learning by doing" to describe as to how active students learn. *Reflective students* perceive a sense of pleasure when learning by themselves by thinking deeply. The term "learning by thinking" could describe Reflective students.

2. *Sensing/Intuitive dimension:* Sensing students like to learn from facts and dislike surprises; moreover, they are good at memorizing facts and like to solve problems by well-established methods. They are patient with details, good at doing hands-on (laboratory) work. They tend to be practical and careful. They do not like courses that have no apparent connection to the real world. On the contrary, *intuitive students* like innovative things and dislike doing the same thing repetitively. They prefer discovering possibilities and relationships and tend to be better at grasping new concepts.

3. *Visual/Verbal dimension*: *Visual students'* remember best visual things, as seen in pictures, diagrams, flow charts, timelines, films and demonstrations. *Verbal students* prefer text description and get more out of written and spoken explanations.

4. *Sequential/Global dimension*: *Sequential students* tend to gain understanding in linear steps, with each step following logically from the previous one, and tend to follow logical stepwise paths when finding solutions. *Global students* tend to solve problems quickly once they have grasped the big picture, and tend to learn in large jumps without seeing connections.

EXPERIMENTAL DESIGN AN RESULTS

This proposed model as illustrative example to shows the similarities and differences between the learning modules generated for FD student's with verbal and visual learning styles. It can be seen that the learning content has been adjusted to meet the student's learning styles. Moreover, the user interface in Figure 5 (for FD students) is much simpler than that in Figures 3 and 4 (for FI students), which show part of the adjustments made for the students with different cognitive styles. The user interface for FI students (Figure 3) included the course schema in the left panel and a navigation button on the top of the screen, while that for the FD students only had the title of current course unit. A perusal of literature proved that most of the FD students were likely to be affected by contexts. Although the difference between Figure 3 and Figure 4 was not significant, the impact of additional cognitive load could be avoided for FD students via considering those interface details in designing each part of the learning system figure 3.

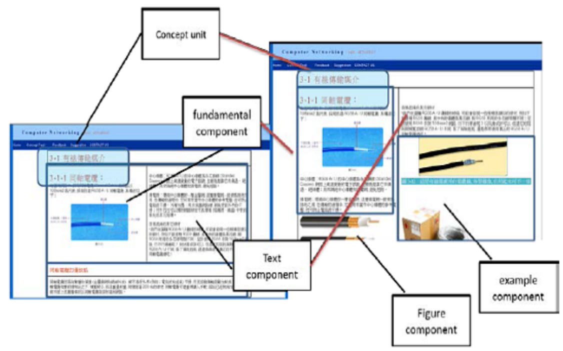

Fig 3. Learning modules for FD students with verbal and visual learning styles

The rating of each dimension ranges from -11 to +11. Based on individual student's ratings in each dimension, the learning system adapts the instructional strategy to meet their needs. The instructional strategies of the proposed system are given in the column data (Table 3).

The pre-test was aimed to confirm the two groups of students had the equivalent basic knowledge required for taking this particular subject unit. It was composed of 15 true-or-false items and 15 multiple-choice items with a full score of 100. The post-test consisted of 10 true-or-false items and 23 multiple-choice items with a full score of 100. It focused on evaluating the student's knowledge about network ontology, device and know-how based on the given scenario. Both the pre-test and post-test were designed by the teacher who taught the Computer Networking course to the two groups of students. Moreover, the test items were mainly in the knowledge and understanding levels of the taxonomy and Bloom's (1956) educational objectives. The tests were evaluated by two science educators for expert validity shown in the figure 4.

The cognitive load measure used in this study was proposed by (Akbulut , 2012). It consisted of two dimensions, that is, mental load and mental effort. Each dimension contained two items. The Cronbach's alpha values of the two dimensions were 0.72 and 0.71 respectively.

Furthermore, the Motivated Strategies for Learning Questionnaire (MSLQ) with a five-point Likert rating

Table 3: Results of continuous adaptive principles

Learning style	Content adjusting principles	Component selecting rules
Active	Provide examples to further explain the learning content. Provide illustrative examples to link the knowledge to real life or to show the process of solving problems.	Text: Fundamental Figure: Fundamental Example: Fundamental + supplementary
Reflective	Remind Students to review what they have learned. Encourage student to think of possible questions or pplications. Encourage students to write short summaries or notes based on what they have learned in their own words.	Text: Fundamental Figure: Fundamental Example: Fundamental
Sensing	Provides specific example of concepts and procedures, and find out how the concepts can be applied to practical applications.	Text: Fundamental Figure: Fundamental + supplementary Example: Fundamental + supplementary
Intuitive	Provide interpretations or theories related to the course content. Remind the students by providing illustrative examples to address some easy-to-confuse concepts.	Text: Fundamental + supplementary Figure: Fundamental Example: Fundamental + supplementary
Visual	Provide the students which more visual materials, such as diagrams, sketches, schematics, photographs, or floe charts.	Text: Fundamental Figure: Fundamental + supplementary Example: Fundamental + supplementary
Text	Provide students with more text materials.	Text: Fundamental+ supplementary Figure: Fundamental Example: Fundamental
Sequential	Present learning materials in a logical order.	Text: Fundamental+ supplementary Figure: Fundamental Example: Fundamental Scope: a concept or learning step
Global	Enable students to browse through the entire chapter to get an overview before learning.	Text: Fundamental with an abstract Figure: Fundamental + supplementary Example: Fundamental + supplementary Scope: a chapter

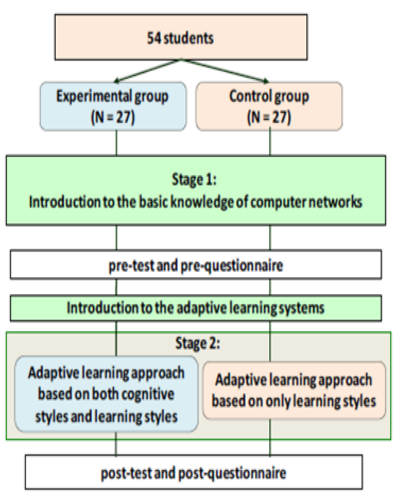

Fig. 4. Shows the procedure of the experiment

scheme was used to evaluate the learning motivation of the students. The questionnaire was revised from the measure proposed by (Aroyo, 2006). It consists of 29 items covering six dimensions, that is, intrinsic goal orientation, extrinsic goal orientation, task value, control beliefs for learning, self-efficacy and test anxiety. The Cronbach's alpha values of the six dimensions are 0.67, 0.73, 0.67, 0.72, 0.73 and 0.74 respectively.

CONCLUSION

Adaptive learning has been identified as being an important and challenging issue of computers in education. In the past decades, various methods and 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 previous studies as a reference for adapting learning content or organizing the content. In most studies, only one or two dimensions of a learning style model are considered while developing the adaptive learning systems. Moreover, in most of the systems, only a fixed type of user interface is provided. In this article, we propose an adaptive learning system developed by using both learning styles and cognitive styles to adapt the user interface and learning content for individual students. Moreover, the full dimensions of a learning style model have been taken into account. The experimental results showed that the proposed system could improve the learning achievements of the student's. Moreover, it was found that the student's mental load was significantly decreased and their belief of learning gains was increased.

FUTURE WORK

The present study mainly focused on the use of learning styles and cognitive styles in providing a personalized user interface and 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. Another limitation of this study is that the experimental group received more treatment than the control group owing to the use of different adaptive learning approaches. In the near future, we plan to apply the proposed approach to other applications with larger sample sizes and analyze the size effect as well. In the meantime, we also plan to expand the learning system by taking more parameters into consideration with more precise experiment design to control possible factors that might affect student's learning performance. Furthermore, it is expected that the learning portfolios of students can be analyzed and more constructive suggestions can be given to teachers and researchers accordingly.

REFERENCES

Aroyo, L., Dolog, P., Houben, G. J., Kravcik, M., Naeve, A., Nilsson, M. and Wild, F. 2006. Interoperability in personalized adaptive learning. *Educational Technology & Society,* 9(2): 4-18.

Akbulut. Y. and 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. https://doi.org/10.1016/j.compedu.2011.10.008

Bloom, B. 1956. *Taxonomy of Educational Objectives. Handbook I: The Cognitive Domain*. New York, NY: David McKay, 1956.

Carver, C. A., Jr., Howard, R. A. and Lane, W. D. 1999. Enhancing student learning through hypermedia courseware and incorporation of student learning styles. *IEEE Transactions on Education,* 42(1): 33–38. https://doi.org/10.1109/13.746332

Chen, S. Y. and Ford R. D. 2000. Cognitive styles and hypermedia navigation: Development of a learning model. *Journal of the American Society for Information Science and Technology,* 53(1): 3-14. https://doi.org/10.1002/asi.10023

Chen, S. Y. and Macredie, R. D. 2011. Cognitive styles and hypermedia navigation: Development of a learning model. *Journal of the American Society for Information Science and Technology,* 23(8): 5-18.

Chen, S. Y. and Macredie, R. D. 2012. Multiobjective optimization and comparison of nonsingleton type-1 logic system. Cognitive systems.*Journal of the American Society for Information Science and Technology,* 55(7): 3-20.

Chen, S. Y., Fan, J. P. and Maredie, R. D. 2004. Navigation in hypermedia learning systems: Experts vs. novices. *Computers in Human Behavior,* 25(3): 243-266.

Chen, S. Y., Fan, J.P. and Maredie, R. D. 2008. Evaluation of an intelligent web-based language tutor.*University of Oxford,United Kingdom,* P. 275-281

Chen, S. Y., Fan, J. P. and Maredie, R. D. 2011. Evaluating an intelligent tutoring system for design patterns: the DEPTHS.*Educational technology &socity,* P. 111-130.

Chiou, C. K., Tseng, Judy C. R., Hwang, G. J. and Heller, S. 2008. An adaptive navigation support system for conducting context-aware ubiquitous learning in museums. *Computers & Education,* 55(2): 834-845. https://doi.org/10.1016/j.compedu.2010.03.015

Chiou, C. K., Tseng, Judy C. R., Hwang, G. J. and Heller, S. 2009. Knowledge representation using multilevel hierehical model in intelligent tutoring system, International conference on advances in computer science and technology, P. 323-346.

Chiou, C. K., Tseng, Judy C. R., Hwang, G. J. and Heller, S. 2010. A survey about fuzzy cognitive maps papers, *International journal of computational cognition,* P. 27-33.

Chiou, C. K., Tseng, Judy C. R., Hwang, G. J. and Heller, S. 2011. Neuro fuzzy reasoned for student modelling,in proc.6th inter.conf on Advanced learning technologies, P. 743-756.

Coffield, K. and Moseley, S. 2004. Interoperability in personalized adaptive learning. *Educational Technology & Society,* 9(5):27-34.

Felder, R. M. and Silverman, L. K. 1988. Learning and teaching styles in engineering education. *Engineering Education,* 78(7): 674-681.

Felder, R. M. and Silverman, L. K. 1998. Fuzzy user modelling for adaptation in educational hypermedia,The knowledge engineering review, P. 1-38.

Felder, R. M. and Soloman, B. A. 1997. Index of learning style questionnaire. Retrieved from http://www.engr.ncsu.edu/learningstyles/ilsweb.html

Filippidis, S. K. and Tsoukalas, I. A. 2009. On the use of adaptive instructional images based on the sequential-global dimension of the Felder-Silverman learning style theory. *Interactive Learning Environments*, 17(2):135-150. https://doi.org/10.1080/10494820701869524

Lin,C. M. 2007.Combination study of fuzzy cognitive map.Energy and Environment,Archives of psychology, *Computers & Education* 2: 65-69.

Lin,C. 2012. FAQ system in specific domain basedon concept hierarchy and question type *IEEE Transactions on Education*, P. 281-284.

Papanikolaou, K.A. 2002. Personalizing the interaction in a web-based educational hypermedia system: the case of INSPIRE,*Journal of the American Society for Information Science and Technology,* P.213-267.

Papanikolaou, K.A. 2006. Layered evaluation of adaptive learning systems,*Int.j. cont.Engineering education and lifelong learning*, P. 402-421.

Thomson, D. 1995. Towards a negotiable student model for constraint-based ITS, *Interactive Learning Environments,* 83-90S