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A Learning Style Perspective to Investigate the Necessity of Developing Adaptive Learning Systems

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ABSTRACT

Learning styles are considered to be one of the factors that need to be taken into account in developing adaptive learning systems. However, few studies have been conducted to investigate if students have the ability to choose the best-fit e-learning systems or content presentation styles for themselves in terms of learning style perspective. In this paper, we aim to investigate these issues by using two versions of an educational game developed based on the sequential/global dimension of the learning style proposed by Felder and Silverman. The experimental results showed that the choices made by the students were not related to their cognitive process or learning style; instead, most students made their choices by intuition based on personal preferences. Moreover, the students who learned with learning style-fit versions showed significantly better learning achievement than those who learned with non-fit versions. Consequently, it is concluded that students preferring one game over another does not necessarily mean that they will learn better with that version, revealing the importance and necessity of developing adaptive learning systems based on learning styles.

Keywords

Learning styles, Cognitive process, Human factors, Educational computer games, Adaptive learning

Introduction

The provision of personalized or adaptive learning support for individual students has been recognized as being one of the most important features of e-learning systems (Tseng, Chu, Hwang, & Tsai, 2008). By referring to personal information, adaptive learning systems can either present personalized content for individual students or guide them to learn by providing a personalized path (Brusilovsky, 2001). In the past decade, many personalized 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). For example, Huang and Yang (2009) designed a semantic Web 2.0 system to support different types of knowledge and adaptive learning. They found that combining the advantages of blogs and wikis enabled students to comprehend various types of knowledge and improve their learning performance. Tseng et al. (2008) developed an adaptive learning system to plan personalized learning paths for individual students by selecting and linking the learning units based on their knowledge levels. It was found that the students who learned with the adaptive learning materials had significantly better learning achievement than those who learned with the non-adaptive materials.

Among those factors that affect the provision of personalized learning contents or paths, learning styles have been recognized by researchers as being an important factor (Filippidis & Tsoukalas, 2009). Keefe (1987) stated that "learning style is a consistent way of functioning that reflects the underlying causes of learning behavior." He further indicated that learning style is both a characteristic which indicates how a student learns and likes to learn, as well as an instructional strategy informing the cognition, context and content of learning (Keefe, 1991). Previous studies have reported that students' learning performance could be improved if proper learning style dimensions could be taken into consideration when developing adaptive learning systems (Filippidis & Tsoukalas, 2009; Graf, Liu, & Kinshuk, 2010; Hauptman & Cohen, 2011).

Although adaptive learning has been widely discussed and has been recognized as being an effective approach for helping students improve their learning performance, few studies have been conducted to investigate whether

students can choose the best-fit e-learning systems for themselves. In this study, an experiment has been conducted which provided students with two versions of an educational computer game based on the sequential/global learning style dimension proposed by Felder and Silverman (1988) to investigate the following research questions:

1. Can students choose educational computer games that fit them best from the learning style perspective?
2. Is there any difference between male and female students in choosing educational computer games?
3. What are the factors that affect students' choice of educational computer games?

Moreover, the learning achievement of the students who learned with learning style-fit versions is compared with that of those who learned with non-fit versions. From the experimental results, we aim to show the importance and necessity of developing adaptive learning systems based on learning styles; that is, if students of both genders are incapable of choosing a game that best fits their learning style, and if learning styles do have a significant impact on students' learning achievements, it is then inferred that the development of adaptive learning systems based on learning styles is needed.

Literature review

Adaptive learning systems refer to the computerized learning systems that adapt learning content, presentation styles or learning paths based on individual students' profiles, learning status, or human factors (Chen, Liu, & Chang, 2006; Tseng et al., 2008). Brusilovsky (1996) has presented several strategies for developing adaptive learning systems, such as the Curriculum Sequencing method that provides individual students with the most suitable sequence of learning the subject units, the Intelligent Analysis method that identifies students' solutions and provides learning supports accordingly, the Interactive Problem-Solving Support strategy that provides students with personalized assistance in each problem-solving step, the Example-based Problem-Solving approach that suggests the most relevant cases or examples to students, the Adaptive Presentation approach that adapts the learning content based on each individual's knowledge level or personal characteristics, and the Adaptive Navigation Support approach that provides personalized learning paths (or links) to students based on their knowledge levels or personal characteristics. In the past decades, researchers have developed adaptive learning systems based on these approaches and have shown the effectiveness of the developed systems (Karampiperis & Sampson, 2005, 2009; Klašnja-Milićević, Vesin, Ivanović, & Budimac, 2011; Romero, Ventura, & de Bra, 2009).

Among various human factors, learning styles have been considered as an important factor for developing adaptive learning systems (Filippidis & Tsoukalas, 2009). There have been several learning style theories proposed by researchers, such as those proposed by Keefe (1979), Kolb (1984) and Felder and Silverman (1988). In the past decade, several studies have attempted to develop adaptive learning systems based on learning styles. For example, Tseng, Chu, Hwang and Tsai (2008) developed a personalized learning system by taking both the knowledge levels and the learning styles of students into account. Later, Kinshuk, Liu and Graf (2009) proposed an adaptive learning approach by analyzing the interactions between students' learning styles, behaviors, and their performance in an online course that was mismatched regarding their learning styles to find out which learners needed more help, such that proper learning supports could be provided accordingly. Graf, Liu and Kinshuk (2010) further investigated the navigational behavior of students in an online course within a learning management system to look at how students with different learning styles prefer to use and learn in such a course. They found that students with different learning styles used different strategies to learn and navigate through the course.

Furthermore, several studies have reported positive effects of employing learning styles in developing adaptive learning systems. For example, Hauptman and Cohen (2011) examined whether students with a certain learning style would benefit more from learning 3D geometry than other students. Their findings indicated a differential impact of virtual environments on students with different modal and personal learning styles. Bolliger and Supanakorn (2011) examined the effects of learning styles on learner perceptions of the use of interactive online tutorials by categorizing the students into five learning style categories and four learning modalities. The responses to a questionnaire regarding survey dimensions were analyzed in order to ascertain differences based on learning style dimensions, gender and class standing.

Among those learning style theories, the Felder–Silverman learning style has been widely adopted and has been validated by various studies (Mampadi, Chen, Ghinea, & Chen, 2011; van Zwanenberg, Wilkinson, & Anderson,

2000). For example, Filippidis and Tsoukalas (2009) developed a web-based adaptive educational system based on the sequential-global dimension of Felder–Silverman's learning style theory. The adaptive learning system provides different versions of images to present the same content with different detailed levels; that is, a detailed version of the images is given for sequential learning style students, while a non-detailed version is presented to global learning style students. Recently, Hwang, Sung, Hung and Huang (2012) developed an adaptive learning system based on this similar learning style approach 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.

In this study, two versions of an educational computer game were developed based on the sequential/global dimension for investigating the students' ability and decision-making process in choosing the best-fit learning system.

Experiment design

Participants

As the educational computer games were developed for an elementary school natural science course, a total of 288 students in an elementary school in southern Taiwan voluntarily participated in the study. All of the students were taught by the same instructor who had taught that natural science course for more than ten years.

Measuring tools

The measuring tool adopted in this study was the Index of Learning Styles (ILS) Questionnaire developed by Soloman and Felder (2001) based on the learning styles proposed by Felder and Silverman (1988). The ILS measure consists of four dimensions, that is, sensing/intuitive, visual/verbal, active/reflective and sequential/global, each of which contains 11 items. In this study, the "sequential/global" dimension was adopted. Some of the questionnaire items of this dimension are "I tend to (a) understand details of a subject but may be fuzzy about its overall structure; (b) understand the overall structure but may be fuzzy about details." and "Once I understand (a) all the parts, I understand the whole thing; (b) the whole thing, I see how the parts fit." Choosing "a" indicates that the "sequential" tendency degree is increased; otherwise, the "global" tendency degree is increased.

In addition, a pre-test and a post-test were conducted to evaluate the learning achievements of the students. Both the tests were developed by two experienced natural science teachers. The pre-test aimed to evaluate the students' basic knowledge of the natural science course content, while the post-test aimed to evaluate the students' knowledge in identifying and differentiating the plants on the school campus after the learning activity. The pre-test contained both multiple-choice and fill-in-the-blank items; its perfect score was 100. The post-test contained twenty multiple-choice items; its perfect score was 60.

Sequential and global style educational computer games

Educational computer games have been recognized as being a good way of providing a more interesting learning environment for acquiring knowledge (Cagiltay, 2007; Hwang & Wu, 2012; Papastergiou, 2009; Tüzün, Yılmaz-Soylu, Karakus, Inal, & Kızılkaya, 2009; Wang & Chen, 2010). Various studies have shown that educational computer games can enhance students' learning interest and motivation (Burguillo, 2010; Ebner & Holzinger, 2007; Hwang, Sung, Hung, Yang, & Huang, 2012; Hwang, Wu, & Chen, 2012; Liu & Chu, 2010; Dickey, 2011; Harris & Reid, 2005). For example, Prensky (2001) pointed out that the purpose of combining games with teaching is to provide learners with interactive learning chances as well as to trigger their learning motivation. Inal and Cagiltay (2007) investigated the flow experiences of children in an interactive social game environment, and found that the challenge and complexity elements of the games had a greater effect on the flow experiences of the children than clear feedback.

In this study, two versions of an educational computer game were developed for the "knowing the plants on the school campus" unit of an elementary school natural science course based on the sequential/global dimension of the

Felder–Silverman learning style. The objective of the subject unit is to foster the students' competence in identifying and differentiating a set of target plants.

The game was implemented by employing the RPG Maker developed by Enterbrain Incorporation. The background of the game is an ancient kingdom in which the people are infected by poisoned water in a river. Following the hints from an ancient medical book, the king decides to look for the plants that are able to cure his people.

The game designed for sequential style learners provides a "step-by-step" interface to guide the students of this style to complete the learning missions, since they tend to think linearly and learn in small incremental steps (Felder & Silverman, 1988). Figure 1 shows the interface of the sequential style game. The learners are guided by this version of the game to the next mission only after the present mission has been completed.

Figure 1. The sequential style game

On the other hand, the global style game provides a "global mission map" that enables the students to select any mission or jump to any game scene, since they tend to learn with holistic thinking processes in large leaps (Felder & Silverman, 1988). Figure 2 shows the interface of the global style version of the educational computer game.

It should be noted that there is no specific logical order suggested by the teacher for learning about the plants. The only difference between the two versions of the game is the way of presenting the learning materials. In the sequential style version, the students learn about one plant at a time in the Chinese character order. Only after they complete the learning tasks of one plant (i.e., they have learned all of the features and details of that plant), are they guided to the next plant; that is, they learn the details of individual plants sequentially. On the other hand, the global version presents all of the plants related to the learning activity via the map; that is, the students learn with a global view of the whole content. Such a style-based interface design is based on the suggestions given by Mampadi et al. (2011). Following such a design principle, the students of both styles receive the same learning content and an equal

amount of information about the learning content and learning tasks, and hence the challenges of the two versions can be viewed as equal.

Figure 2. The global style game

Experiment procedures

Before the experiment, the students completed the learning style questionnaire so they could be categorized according to sequential or global style. Following that, a one-hour presentation was made by the teacher to show them the two versions of the educational computer game, including the differences and similarities between the two versions; moreover, the students were informed that the two versions of the game had identical content related to the "knowing the plants" unit of the natural science course. After the presentation, the students were asked to make the choice between the two versions of the game and write down their reasons for the choice.

Results

Relationships between students' learning styles and their choices of the e-learning systems

From the learning style questionnaire result, it was found that 134 of the participants were sequential style students, while 154 were global style learners. Table 1 shows the ratio of the choices made by the different learning style students. It is found that 86.1% of the students chose the global style system, while only 13.9% chose the sequential style system; that is, most of the students preferred the global style version of the game. Moreover, 86.5% of the sequential style students chose the global style system while only 14.3% of the global style students chose the sequential style system.

Table 1. Descriptive data of students' learning styles and their choices of the educational computer game

		Choices of the educational computer game		Total
		Sequential	Global	
Students' Learning Style	Sequential	18 (13.5%)	116 (86.5%)	134
	Global	22 (14.3%)	132 (85.7%)	154
Total		40 (13.9%)	248 (86.1%)	228

To further investigate the relationships between students' learning styles and their choice of educational game, Chi-Square analysis was applied to the questionnaire data, as shown in Table 2. It is found that the correlation between the students' learning styles and their choice of the learning systems was not statistically significant ($r = 0.44$, $p > .05$). Consequently, it is concluded that the choices made by the students were not related to their learning styles; that is, the students did not choose the educational games by considering their underlying needs for learning effectiveness.

Table 2. The Chi-Square result of students' learning styles and their choices of educational games

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	.044	1	.835
Likelihood Ratio	.044	1	.835
Linear-by-Linear Association	.043	1	.835
N of Valid Cases	288		

Relationships between genders

Table 3 shows the descriptive data of male (N = 158) and female (N = 130) students in choosing the two versions of the educational computer game. It is found that 137 out of 154 male students and 121 out of 130 female students chose the global style system, indicating that both the male and the female students preferred the global style version of the educational computer game. Moreover, it was found that 81.1% of the male sequential style students (60 out of 74) and 93.3% of the female sequential style students (56 out of 60) chose the global style game.

Table 3. Descriptive data of students of different genders in choosing the educational computer games

			Choices of the educational computer game		
Gender			Sequential	Global	Total
Male (N = 154)	Learning Style	Sequential	14 (18.9%)	60 (81.1%)	74
		Global	17 (20.3%)	67 (79.7%)	84
Female (N = 130)	Learning Style	Sequential	4 (6.7%)	56 (93.3%)	60
		Global	5 (7.2%)	65 (92.8%)	70
Total			40 (13.9%)	248 (86.1%)	288

Table 4 shows the Chi-Square analysis results. It is found that the correlations between the choices of the educational computer games and the learning styles of male and female students are $r = 0.43$ ($p > .05$) and $r = 0.11$ ($p > .05$), respectively, which were not statistically significant. Consequently, it is concluded that, for both genders, the choices of the educational computer games were not related to their learning styles.

Table 4. The Chi-Square result of the choices of educational computer games for male and female students of different learning styles

Gender		Value	df	Asymp. Sig. (2-sided)
Male	Pearson Chi-Square	.043	1	.835
	Likelihood Ratio	.043	1	.835
	Linear-by-Linear Association	.043	1	.835
	N of Valid Cases	158		
Female	Pearson Chi-Square	.011	1	.915
	Likelihood Ratio	.011	1	.915
	Linear-by-Linear Association	.011	1	.915
	N of Valid Cases	130		

The factors that affected the students in choosing the educational computer games

In order to investigate the factors that affected the students in choosing the educational computer games, their feedback was analyzed. Table 5 shows descriptive statistics of the feedback from the students in stating the reasons for making their choices. It was found that 73.9% of the participants responded that "The game I chose looks more interesting than the other;" 71.7% of the participants made choices because they felt that "The game I chose looks more relaxing;" 65.2% of the participants commented that "Such an operational interface conforms to my previous experiences of playing games" and 66.7% stated that "The design of the game seems to be easier to operate."

To sum up, the factors that affect the students' choice of game include "interesting," "relaxing," "easy to use" and "conforming to previous experiences," which are all irrelevant to the cognitive process of individual students with different learning styles. Consequently, it is necessary to develop adaptive learning systems for guiding students to learn in an appropriate way, including providing a personalized learning interface or paths to present learning content in the most beneficial manner for individual students with different learning styles.

Table 5. Descriptive statistics of factors that affect students in choosing educational computer games

	Factors	Global style students who chose sequential style game (N = 116)		Sequential style students who chose global style game (N = 22)		Total (N = 138)	
1.	The game I chose looks more interesting than the other.	86	(74.1%)	16	(72.7%)	102	(73.9%)
2.	The game I chose looks more relaxing.	84	(72.4%)	15	(68.2%)	99	(71.7%)
3.	Such an operational interface conforms to my previous experiences of playing games	74	(63.8%)	16	(72.7%)	90	(65.2%)
4.	The design of the game seems to be easier to operate.	75	(64.7%)	17	(77.3%)	92	(66.7%)

Learning achievements of the style-matching and non-matching groups

An extended experiment was conducted to further investigate the effect of learning styles on the learning achievement of the students. As a number of the students failed to participate in this extended activity, the pre-test and post-test scores of 127 style-matching and 125 non-matching students were analyzed.

From the pre-test, it was found that the mean values and standard deviations were 88.20 and 6.73 for the experimental group, and 87.73 and 8.60 for the control group. The t-test result (t = .483, p > .05) shows that there was no significant difference between the two groups, implying that they had equivalent prior knowledge before the learning activity.

After the learning activity, ANCOVA was conducted by using the students' pre-test scores as the covariate and the post-test scores as the dependent variable to exclude the impact of the pre-test on their science learning. Table 6 shows the ANCOVA results of the post-test. It is found that the learning achievement of the style-matching students was significantly better than that of the non-matching students, indicating that learning style could be an important factor in developing adaptive learning systems or providing personalized learning supports.

Table 6. Descriptive data and ANCOVA result of the post-test results

Variable	Group	N	Mean	S.D.	Adjusted Mean	Std. Error.	*F*
Post-test	Experimental group	127	34.50	12.21	34.35	.97	6.18*
	Control group	125	30.78	11.73	30.94	.98	

Note. $^{*}p < .05$

Discussion and conclusions

In this study, we investigate students' perceptions in choosing the most-beneficial educational systems from the perspective of learning styles. The participants were asked to select one of two versions of an educational game developed based on the sequential/global dimension of the learning style proposed by Felder and Silverman.

For the first and the second research questions, the experimental results of 288 students showed that the students were unable to choose educational computer games that fit them best from the learning style perspective; moreover, there was no difference between male and female students in choosing the games. In terms of the third research question, it was found that the choices they made were not related to their cognitive process or learning styles; instead, most students chose the e-learning systems based on intuition or preference, such as "interesting," "relaxing," "easy to use" and "conforming to previous experiences."

Furthermore, the pre-test and post-test results showed that the learning achievements of the style-matching group outperformed those of the non-matching group. Therefore, it is concluded that students preferring one game over another does not necessarily mean that they will learn better with what they choose, revealing the importance and necessity of developing learning systems that are able to provide individual students with personalized learning content to best benefit them. That is, this study provides evidence for supporting the development of adaptive learning systems, in particular, for those studies that employ learning styles as a factor for adapting learning content, presentation styles and learning paths for individual students.

To sum up, this study contributes several interesting findings to the community of technology-enhanced learning: (a) Students learn better with the version which has been designed for their learning style. This demonstrates the importance of adaptive learning systems which are based on learning styles. (b) Students do not necessarily choose the version which has been designed for their learning style. This is very important, because most adaptive systems create an initial user model based on individual students' answers to a questionnaire or choices of a set of parameters which are always assumed to be "reasonable." The results of the experiment demonstrate that this might be unsafe since users' choices are likely to be irrelevant to their learning performance. This can have a significant impact to the design of adaptable and adaptive learning systems.

On the other hand, although this study provides some significant experimental results, the use of the computer educational games in this study might not be able to represent the common features of most learning systems; moreover, the implications of this study are limited owing to the investigation being conducted on only one dimension of a learning style. Some researchers have attempted to investigate the issues concerning game-based learning from different aspects in different application contexts, such as user participation (Hoffman & Nadelson, 2010), learning interactivity and challenges (Susaeta et al., 2010), learning attention (Russell & Newton, 2008), collaborative learning (Huang, Yeh, Li, & Chang, 2010; Paraskeva, Mysirlaki, & Papagianni, 2010), gender differences (Kinzie & Joseph, 2008) and the teachers' considerations (Kebritchi, 2010). In the future, it would be worth conducting further studies to investigate those relevant issues by taking different learning dimensions into account.

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