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Educational virtual worlds, learning styles and learning effectiveness: an empirical investigation

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Abstract

Virtual Worlds is a promising new medium for educational activities that should address several learning styles and preferences. Learning styles has long been considered a very crucial parameter for designing effective learning experiences. In this study, two learning modalities, i.e. a scenario-based virtual world and a simple web site have been employed in order to investigate their effects on students' learning effectiveness with respect to their learning style in the Felder-Silverman taxonomy. A randomized controlled crossover study is presented and the main findings and implications are discussed.

Keywords: virtual worlds, learning effectiveness, learning styles, learning modalities

Introduction

Virtual Worlds are shared 3D spaces for multi-user communication and interaction (Bartle, 2003). In the last few years a number of desktop Virtual Worlds, serving either as generic places for social interaction or as multi-user online games have become increasingly popular. Given that the use of Virtual Reality technologies in education has led to encouraging results (Bell&Fogler, 1995), Virtual Worlds may be a promising new medium for educational activities (Dickey, 2005; Childress & Braswell, 2006; Cheal, 2007). Although they do not seem to be able to replace more traditional educational media, the introduction of this technological paradigm in education has potential to improve the overall learning experience. A theoretical as well as practical challenge however is to evaluate its application to various types of learners.

Learning styles are defined as one's preferred methods for perceiving and processing information (Kolb, 1984) or as general tendencies to process information in different ways. They describe the learner's preferences and strengths in the actual, psychological and cognitive processes that are employed during learning. Due to these differences, it appears that students typically present a favourable tendency towards some courses while having difficulties in others. In many cases the most important factor for the success of a course is finding the common ground between the teaching style and the students' learning styles. Thus during the learning process it is very important for teachers to apprehend the differences in the learning style of students. Translating this to learning material that utilizes new technologies, the designer of the learning material has to take into consideration the effects of the new technological paradigms to various learners. Additionally, students may also benefit greatly by realizing their own strengths in learning and adapting to them or enhancing them (Felder & Spurlin, 2005).

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In this study, two learning modalities, a virtual world and a simple web site with the same learning content have been employed in order to investigate their effects on students' learning effectiveness with respect to their learning style in the Felder-Silverman taxonomy.

Virtual Worlds and Education

Virtual Worlds are computer-generated environments, in which multiple users act, communicate and collaborate using embodied representations in a shared space (Bartle, 2003). Although they have been originally related to immersive environments using expensive and specialized hardware, studies have shown that user's presence can be achieved even in non-immersive environments (Sadowski & Stanney 2002). Today's most popular Virtual Worlds, such as Second Life and World of Warcraft, are based on standard desktop technologies. The success, in terms of the very large user base, of these environments is not difficult to explain: the freedom given to users to express themselves, to experiment, to configure their representation and to develop a kind of social life in the artificial environment have shown to be highly desirable (Herman et al., 2006).

Being a highly popular medium in which people tend to spend a lot of hours to communicate and entertain themselves, an important problem that the educational research community sought to investigate was whether Virtual Worlds can be effectively used as learning environments (Dickey, 2003; Cheal, 2007). Given that this fairly new medium of presentation, interaction and communication has significant differences compared to traditional learning paradigms, researchers attempted to study its effects on the learning outcomes and the circumstances and preconditions under which Virtual Worlds are to be used. A number of environments, prototypes and case studies have been setup in order to draw results on the use of Virtual Reality in education in the last two decades (Dede, 1995; Johnson et al., 1998; Dickey, 2005). These studies vary in terms of the educational content, the number of simultaneous users that can coexist in the environment, the user interface, the learning models that have been applied, etc. Interacting with virtual worlds has proven to be highly motivating for students and it usually draws their interest and enthusiasm. However, one has to note that virtual worlds cannot effectively substitute all other existing learning approaches. They should rather be faced as a complementary medium and should be integrated with other educational activities (Bell & Fogler, 1995).

Learning Styles

Learning styles relate to the behaviour of learners in interacting with the educational environment, receiving and perceiving and processing new information. Pask had identified differences between holist and serialist information processing styles as early as 1976 (Pask, 1976). In order to address the need of classifying students according to their characteristics, strengths and preferences during the educational process, learning styles models - or taxonomies - have been proposed. Learning style models have been used in education and are becoming increasingly popular. Hain utilized the learning style models of Kolb (Kolb, 1984) and Dunn (Dunn, 1990) to develop teaching strategies for Physics, Algebra and Trigonometry (Hain, 1999); she then proposed teaching techniques that appeal to the various learners. Sutliff highlighted the importance of using a balanced teaching approach and proposed general directions towards reaching all of students, especially in culturally divided classrooms (Sutliff, 2001); the Kolb Learning Styles Inventory (LSI) was at that time administered to junior level students.

A popular learning style model was proposed by Felder and Silverman (Felder & Silverman, 1988). Relations between learning styles of that model and other models (Kolb, 1984), the Meyers-Briggs Type Indicator (Lawrence 1994), modality theory (Barbe, 1979), are presented in (Felder & Spurlin, 2005). For our research we have chosen this model, due to its simplicity for students and its applicability. It is also a widely known and recognized model that has been used and validated in several empirical studies. Learning style taxonomies are defined by distinct learning characteristics. In the selected model a pair of opposing characteristics represents an axis in a multidimensional space. Students are then classified according to their preference towards one of the opposing characteristics for each pair. Student preferences are considered continua rather than discrete values, although it may sometimes be useful to simplify this model for analysis. The learning styles of students are described using four dimensions, defined by the following pairs of opposing characteristics:

Table 1. Learning Styles Dimensions

sensing: concrete thinker, practical, oriented towards facts and procedures	*intuitive*: abstract thinker, innovative, oriented toward theories and underlying meanings
visual: preferring visual representations such as pictures, diagrams, flow charts etc.	*verbal*: preferring written and spoken explanations
active: learning by trial, enjoying group work	*reflective*: learning by thinking things through, preferring to work alone or with a single familiar partner
sequential: perceiving information step by step	*global*: having a global perspective of the presented information

These characteristics represent student strengths and preferences on perception, type of input, processing style and understanding. The teaching style can also be defined according to a learning style, in terms of content, presentation, student participation and perspective. Felder notes that learning style preferences are not reliable indications of learning styles and weaknesses. Authors note that this is taken into consideration in the formulation of our evaluation methodology i.e. we evaluate effectiveness (knowledge gained through a learning intervention) rather than preference.

Addressing Learning Styles in Virtual Worlds

A number of prototype environments have been built in order to support learning in virtual worlds and the various studies lead to encouraging results concerning the future of this medium as an educational tool. However, given that individuals differ in terms of the ways they can effectively learn new concepts, it is important to investigate whether the performance of students in 3D educational environments depends on their learning style. If any such dependency can be shown, further research about the design of future virtual worlds aspiring to provide effective support to the various learning styles, would be of great value to the educational research community.

Chen, Toh and Wan (Chen et al., 2005) examine the dependency between learning styles and Virtual Reality. They were based on Kolb’s theory of learning styles (Kolb, 1984) and have used two groups to categorize learners: assimilators and accommodators. They set up a study in order to gain empirical data on the relationship between learning styles and the learners' score in three different modes: VR, VR with guided exploration and Non VR. The evaluation results showed a dependency between the students' scores and their learning styles, as accommodators performed better in the non-guided VR environment compared to the Non VR, whilst assimilators' score was vice versa. It is also noticeable that students performed better in the virtual environment with guided exploration independent from their learning style, when compared to the other two modes; this is a result that highlights the importance of the virtual world design decisions for the learning outcomes. The paper by Ford (Ford, 2000) presents a study of Pask's information processing styles (Pask, 1976) and the requirements they raise for the design of virtual environments. The author presents the idea of adaptive virtual learning environments that will be optimized to support individual learners. A number of research directions and design guidelines for virtual environments are presented, but, to the best of our knowledge, no such system has been yet designed and implemented. Bell and Fogler investigate the use of Virtual Reality as an educational tool and examines ways, in which the individual learning styles proposed by Felder and Silverman can be addressed (Bell & Fogler, 1995). They claim that virtual environments are mostly appealing to visual and active learners, whilst global learners may also benefit from the ability to see the big picture and the relationship between abstract concepts and physical realities. They also highlight the fact that a virtual world can contain interactive representations of abstract concepts, which may help sensory learners to get a better understanding of them.

Methodology

The main focus is on investigation of the relationship between two different learning modalities, learning styles and their effect on learning performance. The first learning modality is a static web site (contained a "text enriched with some illustrations" module), while the second learning modality is a virtual world based on a specific educational scenario.

Design of the learning interventions

In this study we chose to have two learning modalities/interventions and students from all the learning style categories. The first learning modality was developed as a simple static web site. The second was developed as a small virtual world. The learning topic for both learning interventions was an introductory short course on Cryptography, i.e. some basic cryptography concepts, symmetric and public key cryptography, SSL.

Regarding the first learning modality, the static web site, we used a typical "text enriched with some illustrations" module. The design of the html pages was as minimal as possible. As for the second learning intervention, the virtual world, we prepared a scenario entitled "Alice in the world of Cryptography". It consists of four environments, each of which introducing one of the following concepts: introduction to cryptography, symmetric key encryption, public key encryption and introduction to SSL. The virtual world material follows the pedagogical approach of guided-inquiry (Colburn, 2000), where students are guided to uncover critical concepts for themselves. Each environment presents a simple real-life scenario and the students are asked to solve a specific problem. E.g. two friends Alice and Bob wish to communicate securely via a public network, whilst an eavesdropper is attempting to gain access to their conversation. The students can navigate freely in the environment and may interact with various objects by pressing buttons and switching between options. They are asked to actively participate, by experimenting with the active elements and by observing the effects of their actions in real time, e.g. they may try to change the size of the encryption key and see the effects on a brute-force decoding attempt. The environment visualizes both concrete objects and abstract concepts and processes, e.g. it shows two users typing and reading messages in their computer, as well as an abstract depiction of the encoding and decoding processes that take place within their computers and a simplified animation of the transmission of their data via a public network. The virtual worlds have been implemented in VRML using AvatarStudio for the visualization and animation of the avatars and VRMLScript for the behaviour of the interactive objects. Figure 1 shows screenshots of the environment.

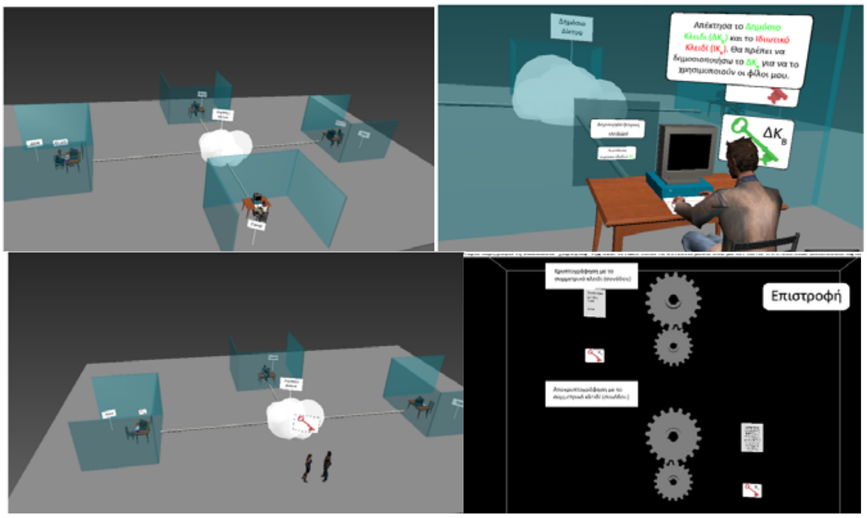

Figure 1. Four Screenshots of the Virtual World

Measures

Learning style was measured using the ILS instrument (Felder and Spurlin 2005), which provides scores for the four learning style dimensions: active -reflective, visual - verbal, sensing - intuitive and sequential - global. Scores range -11 to +11 in increments of two (-11, -9, -5 ...5, 7, 9, 11). Learning performance was measured using an online multiple choice test at the end of each learning intervention. The test contained 5 questions that were designed especially so as to cover the learning objectives of the learning interventions. These questions were pilot tested by two computer security experts.

Subjects and procedure

49 undergraduate students from the department of Product & Systems Design Engineering of the University of the Aegean were actively involved in the experiments. 25 were male (51%) and 24 were female (49%), while all of them were between 18-23 years of age. 34% of the students were following the 5th year of studies, 30% of the students were in the 4th year while the rest of them were following the second or third year. The experimental procedure was organized in two stages: during the first stage the students were invited to answer the ILS questionnaire. Such a process took place 3-4 weeks before the second and the final stage of the experimental procedure. 49 students submitted their learning styles profile according to the ILS. 79,59% of them are Active learners, 20,40% were Reflective, 46,93% were Sensing, 53,06% were Intuitive, 83,67% were Visual while 16,32% were verbal and 36,73% were

Sequential and 63,26% were Global. During the second stage students participated in a lab experiment. Students were randomly assigned in two groups. A counterbalanced design was employed in order to control for order effects, where the two separate groups of subjects received treatments in a different order. Counterbalancing is usually thought of as a method for controlling order effects in a repeated measures design. The first group of students (N=24) interacted first with the static web page (St) and then with the virtual world (VW), while the second group of students (N=25) interacted with the virtual world first and then with the static web page (A group: St→VW and B group: VW→St). As already mentioned students took a knowledge test at the end of each learning intervention. The whole process (interaction with the learning interventions and completion of the knowledge tests) took around 60-70 minutes.

Data analysis and results

A two-factor mixed factorial ANOVA model was used in this study. As already emphasized, the main research aim was to investigate the effects of Learning Styles (LS) and Learning modality/intervention on students' learning performance. Therefore the two factors (which are the independent variables) are the Learning Styles and the Learning modality while the students' learning performance is the dependent variable. In this model Learning modality is the repeated-measures independent variable and the Learning style is the between-group independent variable. Before running the two-factor mixed ANOVA model, some additional tests were performed. An independent samples t-test for differences between the mean scores (for both of the learning performance tests) of male and female subjects was performed. No statistical significant differences were revealed. Table 2 shows that learners from all learning styles performed better under the static learning modality.

Table 2. Learning performance for all Learning Styles

	LS	**N**	**Mean**	**Std. Deviation**		**LS**	**N**	**Mean**	**Std. Deviation**
Static	Active	40	,7100	,24786	**VW**	Active	40	,5750	,28352
	Reflective	9	,7111	,31798		Reflective	9	,4889	,14530
	Sensing	23	,7217	,21523		Sensing	23	,5826	,28228
	Intuitive	26	,7000	,29530		Intuitive	26	,5385	,25152
	Visual	42	,7000	,26595		Visual	42	,5619	,25847
	Verbal	7	,7714	,21381		Verbal	7	,5429	,32071
	Sequential	18	,8000	,20580		Sequential	18	,5778	,26470
	Global	31	,6581	,27419		Global	31	,5484	,26817
	Total	196	,7102	,25640		Total	196	,5592	,26247

Table 3. Effects of independent variables on students' learning performance

Tests of Within-Subjects Contrasts						
Measure: Learning performance						
Source	factor1	Type III Sum of Squares	Df	Mean Square	F	Sig.
factor1	Linear	1,947	1	1,947	38,298	,000
factor1 * LearningStyle	Linear	,128	7	,018	,359	,925

Additionally according to the data analysis (Table 3) it seems that there is a significant effect of learning modality/intervention (factor1) on students' learning performance (F=

38.298, p = 0.000) while the interaction between the learning modality and the learning style is not significant (F= .359, p= .925).

The effect of the between-subjects variable (Learning Style) on the students' learning performance, was found as no statistical significant (F= .375, p= . 916) (Table 4).

Table 4. Effects of Learning style on students' learning performance

Tests of Between-Subjects Effects					
Measure: Learning performance					
Transformed Variable:Average					
Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Intercept	109,834	1	109,834	1263,714	,000
LearningStyle	,228	7	,033	,375	,916
Error	16,340	188	,087		

Discussion and concluding remarks

Results revealed that learning modalities had a significant effect on learning effectiveness. A first comment on the results of the two-factor mixed model is that all students of all learning styles performed better after the interaction with the static web page. It was expected that learners would perform much higher after the interaction with the virtual world. More specifically we would expect that learners with sensing learning style would perform better using a problem-first learning modality (virtual world) method while intuitive learners would do better sing an information-first method (static web page).

However, students did not perform better after the interaction with the virtual world regardless of their learning style. This may be explained by the fact that there is an innovative way of exploring and navigating the virtual world environment and the realistic 3D graphics can distract to a certain extent the learners (Wrzesien, et al., 2010; Papastegriou, 2009). In this study it seems that a more "traditional" type of learning modality such as a static web site is more typical and convenient for the learners who have been used to interact with it in order to get information about the course and learn about the subject matter. This was more or less confirmed by the informal observations of the researchers and the commentaries made by the learners. A second basic remark on the results is that learning styles did not have a significant effect nor did the interaction between the learning modality and the learning style. This calls for a deeper investigation on the characteristics of each learning modality that have an impact on learning effectiveness. Moreover, the non significant effect of learning styles is contradictory with the findings of other studies that indicate that virtual worlds have great potential to support active, sensing, global learners (Dede, 2005). Another parameter that may have influenced the non significant results regarding the learning styles is the factual character of knowledge provided through the learning modalities, while various studies have supported the strength of VWs in collaborative, exploratory and problem-based learning (de Freitas, 2008; Hut, 2007).

A study limitation has to do with the test for the learning effectiveness which was employed in this study; it was quite short, due to the fact that the level of the learning material for both the learning interventions was quite generic. In addition the learning topic of the two learning modalities had not been taught previously in the classroom. Results might be different if we chose a different learning topic (previously taught in the classroom) which is more familiar to the students. Future research effort can provide more evidence on the effect of learning style strength on learning effectiveness in and with/without Virtual

Worlds. Additional courses need to be realized and evaluated; the effect of Virtual Worlds should also be evaluated in a larger scale scenario, e.g. during a full university semester. A course at junior levels could also provide an interesting environment to introduce a Virtual Worlds modality, especially considering the current popularity of Virtual Worlds to kids these days.

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