Learning with Virtual Reality: Its Effects on Students with Different Learning Styles

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Abstract. This study aims to investigate the effects of a virtual reality (VR)-based learning environment on learners with different learning styles. The learning outcomes were measured cognitively through academic performance, and affectively through perceived learning effectiveness and satisfaction. A pre-test-posttest design was employed for this study. A total of 232 students from four randomly selected co-education secondary schools in a city of East Malaysia participated in this study. There was no significant difference in the cognitive and affective learning outcomes for students with different learning styles in the VR-based learning environment. This shows that the VR-based learning environment offers promise in accommodating individual differences pertaining to learning styles.

1 Introduction

In recent years, VR has gained much attention as an alternative approach to traditional learning experiences in schools and colleges. This is mainly because of its ability to provide a highly interactive virtual environment that resembles the real world where user could experience a sense of "being there" when interacting with the virtual objects [1-5]. Research has shown an encouraging array of positive learning outcomes with VR such as better learning in geosciences [6], and better understanding in geometry [7]. In fact, VR has revolutionized how people of all ages learn and work. It has the potential to facilitate the acquisition of higher order thinking and problem solving skills [8]. However, there have been few studies that investigate individual differences in the use of VR [9]. Thus, much research is needed to investigate the impact of VR on learners with different aptitudes [8, 10]. Hence, this study aims to provide an answer to this question: Could VR accommodate learners with different learning styles?

2 Learning Style and VR

People learn in different ways according to their preferred learning style [11]. Kolb [11] defines learning style as one's preferred methods of perceiving and processing

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information based on experiential learning theory. A theory that propagates learning through experience and by experience [12]. It is through the transformation of experience that knowledge is created. Kolb [11] divides the learning process cycle into four learning modes: concrete experience (CE), reflective observation (RO), abstract conceptualization (AC), and active experimentation (AE). His experiential learning model articulates learning is an iterative process that generally begins with a concrete experience, which is followed by reflecting upon what have been observed in these experiences, then to assimilate and integrate conclusions into a theory by abstract conceptualization, and finally to test and apply new theories in new situations. Each individual is most likely to feel most comfortable in one of these four learning modes based on his or her preference along two primary dimensions: the concrete-abstract dimension and the active-reflective dimension [11]. In other words, in perceiving or taking in new information, people characteristically choose between a concrete (feeling) or an abstract (thinking) approach; in processing what they take in, they tend to choose between an active (doing) or a reflective (watching) approach[11]. By plotting the preference along these two primary learning dimension continua, Kolb identifies four types of learning styles: accommodator, assimilator, diverger and converger as shown in Fig. 1.

Accommodators prefer CE and AE. They like doing and experiencing things. They are risk-taker; tend to solve problems in an intuitive, trial-and-error manner; and rely on others for information. Assimilators, on the other hand, prefer RO and AC. They learn by watching and thinking. They are more concerned with abstract concepts and

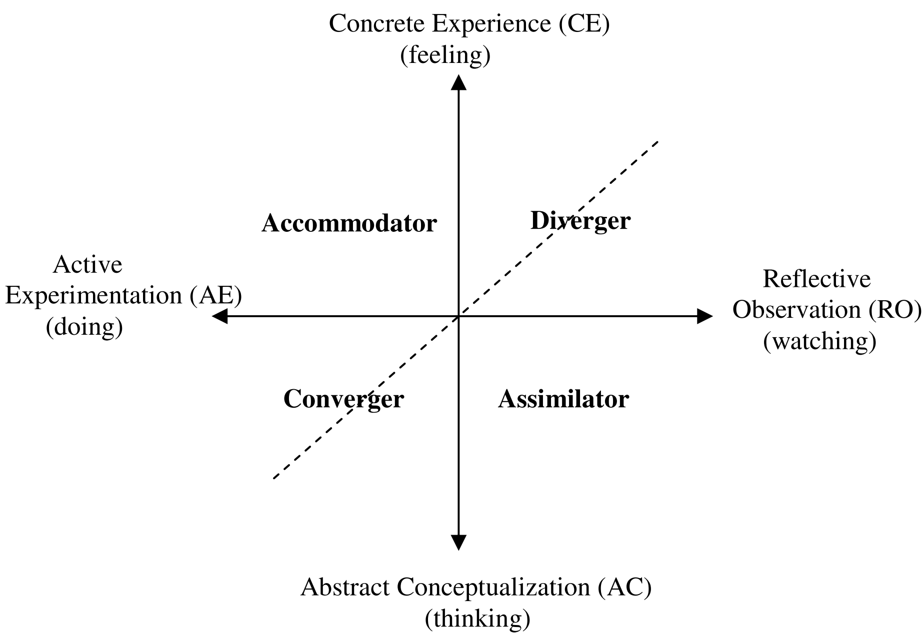

Fig. 1. Kolb's learning styles and learning modes (Adapter from Kolb, 1984)

ideas; good at putting information into a logical form; excel in inductive reasoning; less interested in people and prefer to work alone. Divergers prefer CE and RO. They learn by feeling and watching. They are imaginative; good at seeing things from different perspective; creative; emotional; sensitive to people; and have a broad cultural interest. Convergers, on the other hand, prefer AE and AC. They learn by doing and thinking. They tend to be a problem solver and decision maker; good at finding practical uses for ideas and theories; are generally deductive in their thinking; and relatively unemotional.

Bell and Foyler [13] posit that, experience – the main feature of VR is of great benefits to all learning styles, which means it could provide support to all four of Kolb's learning characteristics. Bricken [14] has also theorized about VR as a tool for experiential learning because VR supports active construction of knowledge through experiment, allows learner to experience the consequences and then to choose and apply the knowledge. Likewise, Fizpatrick [15] asserts that VR learning systems embrace the concepts and models of learning from experience by immersing learners in interactive 3D computer generated world which very closely emulates operations and equipment found in real world.

Chee's [16] - C-Visions (Collaborative Virtual Interactive Simulations), Müller and Ferreira's [17] MARVEL (Virtual Laboratory in Mechatronics) and Chen, Toh & Wan's [18] VR program for novice car driver have provided example applications of how VR can be designed to support Kolb's model of experiential learning. According to Chee [16], the first-person learning experience afforded by virtual environment allows learners to directly experience things that they seek to learn and they have the autonomy and control over their own learning experience. The virtual representations would help learners to concretize ideas, and would help what is otherwise unimaginable, imaginable and experienceable. Ultimately, learners could generalize their learning experiences to form appropriate rules and abstractions for the knowledge learned. VR is capable to support the experiential learning theory because it is able to provide "here-and-now" experience to test theories as well as giving instant feedback to change these theories [17]. Chen, Toh and Wan [18] have also found that their virtual environment that mimics the real world road scenarios provides concrete experience for learners to explore actively, and at the same time the text and image materials presented require reflective observation and abstract conceptualization.

Various learning style models have been developed by scholars such as VARK learning model, Honey and Mumford learning model and Felder-Silverman Learning model. As VR and Kolb learning style model are directly related, Kolb Learning Style Inventory that categorizes one's learning style based on the experiential learning theory was used in this study.

3 Research Objectives

The purpose of this research was to investigate the learning effects of VR on learners with different learning styles. The learning outcomes were measured cognitively through academic performance, and affectively through perceived learning effectiveness and satisfaction. Academic performance was measured through a summative assessment while perceived learning effectiveness and satisfaction were measured subjectively through a questionnaire. A VR software program, V-Frog^{TM} was used as the VR learning material [19]. The specific objectives of this research are:

1. To determine the difference in the cognitive learning outcomes for students with different learning styles when learning with VR
2. To determine the difference in the affective learning outcomes for students with different learning styles when learning with VR

4 Research Hypotheses

In pursuance of the research purpose and objectives, the following four hypotheses were formulated for testing. A detailed description of how the learning styles were categorized is elaborated in section 5.3.4.

H1: There is no significant difference in the performance achievement for accommodator learners and assimilator learners.
H2: There is no significant difference in the overall improvement in performance for accommodator learners and assimilator learners.
H3: There is no significant difference in the perceived learning effectiveness for accommodator learners and assimilator learners.
H4: There is no significant difference in the perceived satisfaction for accommodator learners and assimilator learners.

5 Methodology

5.1 Research Design

A pretest-posttest design was used employed in this study. Participants were randomly assigned to take part in the experiment based on intact classes. Participants followed a lesson on frog anatomy with a desktop VR software program. All participants were required to sit for a pretest and a posttest, to answer the Kolb Learning Style Inventory and a set of questionnaire. Performance achievement was measured by the posttest scores, and the overall improvement in performance was measured by the gain scores (posttest scores minus pretest scores).

5.2 Population and Sample

The population was Form Four science students, aged between 15 and 17 years old of any co-education secondary schools that are well-equipped with multimedia computer laboratories in a city of East Malaysia. These students were chosen because they were within the targeted population as they have started to learn biology in Form Four. Four different co-education secondary schools were randomly selected. For each selected school, one to three intact classes were randomly chosen to participate in this study.

5.3 Instruments

5.3.1 Pretest and Posttest

Both pretest and posttest were similar in content but the order of the questions was different to avoid the set response effect. The tests include questions regarding frog anatomy for the modules covered in this study. The questions include sentence completion with the correct word(s); organ labeling and drawing; and multiple-choice questions. Content validity of these tests was determined by expert judgment. Three subject matter experts were requested to review the test questions and make a judgment about how well these items represent the intended content area. A pilot study was carried out in one co-education secondary school from the same city with forty seven randomly selected Form Four science students to obtain information that was useful to improve these tests. These included the item difficulty index, item discrimination index, and internal consistency measure. Item difficulty index is the proportion of students who answered an item correctly whereas item discrimination index measures how adequately an item discriminates between high scorer and low scorer on an entire test [20]. Six items were deleted in which five items were deleted due to poor discrimination and one was deleted as it had a low corrected item-total correlation ($r = 0.010$). As a result, the final version of the pretest and posttest contains 32 items with an alpha coefficient of 0.846. The item difficulty index was ranging from 0.27 – 0.85 which was of moderate difficulty [21].

5.3.2 Perceived Learning Effectiveness

Perceived learning effectiveness refers to the learning quality experienced by the participants. Based on the instruments of Benbunan-Fich & Hiltz [22], Mark, Sibley, & Arbaugh [23] and Martens, Bastiaens, & Kirschner [24], an eight-item instrument was developed to measure perceived learning effectiveness on the issue of identification, and integration and generalization of the lesson material. A five-point Likert scale ranging from (1) strongly disagree to (5) strongly agree was used to measure perceived learning effectiveness. Sample questions are: I learned a lot of factual information in the topics; I learned to identify the main and important issues of the topics; and I was able to summarize and conclude what I learned. The Cronbach's alpha coefficient for this instrument was 0.867.

5.3.3 Satisfaction

Students' perceived satisfaction in a desktop VR-based learning environment was measured using seven items adapted from Chou & Liu [25]. The original instruments have eight items with an alpha coefficient of 0.8625. This seven-item instrument with a five-point Likert scale with (1) strongly disagree and (5) strongly agree for measuring satisfaction has an alpha coefficient of 0.862. Sample questions are: I was satisfied with this type of computer-based learning experience; I was satisfied with the immediate information gained; and I was satisfied with the overall learning effectiveness.

Ideally, the Cronbach's alpha coefficient of a scale should be greater than 0.7 [26]. Thus, all instruments have a good level of internal validity as measured by the Cronbach's alpha.

5.3.4 Kolb Learning Style Inventory

The Kolb Learning Style Inventory Version 3.1 (KLSI 3.1) was used to categorize the learning style of each participate. The internal consistency for the scale scores of KLSI 3.1 is within the range of 0.52 – 0.84 [27].

Participants were required to complete 12 sentences that describe learning. Each item has four endings and the participants were required to rank the endings for each sentence according to how well he or she thinks each ending describes the way he or she learned.

Based on the Learning Style Inventory scoring, the scores for each learning phases: abstract conceptualization (AC), concrete experience (CE), active experimentation (AE) and reflective observation (RO) were first obtained for each participant. Then, CE score was subtracted from AC scores, and RO score was subtracted from AE scores to have two combination scores. These two combination scores were put on the Learning Style Type Grid to determine the participant's learning style, i.e., accommodator, assimilator, diverger or converger. (see Fig.1). On the Grid, accommodator falls on the top left quadrant; diverger falls on the top right quadrant; converger falls on the bottom left quadrant; and assimilator falls on the bottom right quadrant.

However, for this study, based on the method of Chen, Toh & Wan [18], instead of categorizing into four learning styles: accommodator, assimilator, diverger and converger, a dash diagonal line was introduced to equally separate the grid into two halves as shown in Fig. 1. Any diverger learner or converger learner with the two combination scores that fell below the diagonal line was classified as an assimilator learner. Likewise, if the two combination scores fell above the diagonal line, the participant was classified as an accommodator learner. Thus, assimilator included learners who fulfilled the Kolb's definition of assimilator, diverger learners with stronger Kolb's characteristics of RO than CE, and converger learners with stronger Kolb's characteristics of AC than AE [18]. On the other hand, accommodator included learners who fulfilled the Kolb's definition of accommodator, diverger learners with stronger Kolb's characteristic of CE than RO, and converger learners with stronger Kolb's characteristic of AE than AC [18].

5.4 Software

A desktop virtual reality program, V-Frog^{TM}, was used to provide the virtual learning environment to students. This software was developed and supplied by Tactus Technologies, Inc., New York. This virtual reality-based dissection simulator was developed using virtual surgery technology. Students can have hands-on learning experience with V-Frog^{TM}. They can cut, pull, probe, and examine a virtual specimen, as they would with a real frog. Thus, each dissection is different, reflecting the individual work of each student. Actions are repeatable and the content presentation is nonlinear. In each specimen window, there are viewpoint manipulation tools for students to rotate, slide and zoom the specimen. There is also a reset button to reset the position of the specimen. Additionally, in some specimen windows, dissection tools such as scalpel and tweezer for students to cut and peel the skin are provided. Moreover, there are also query tool that allows students to get information about a part of the specimen; magic wand tool that activates and brings parts of the specimen to life;

Fig. 2. Virtual frog dissection (Courtesy of Tactus Technologies)

and probe tool that examines an orifice in the specimen. Besides, a virtual endoscopy can be conducted with the endoscoping tool to explore the entire alimentary canal. There is also a V-Frog™ lab report to guide students through all the modules, highlighting key points and relationships. The existence of lab report icon on the screen indicates to students that information on the current screen can assist them to complete their lab report successfully.

5.5 Data Collection Procedures

Two weeks before the treatment, respondents were given a pretest regarding frog anatomy and the KLSI 3.1 to answer. Three modules of frog anatomy were selected for this study: Internal Anatomy, Digestive System and Circulatory System. Just before the treatment, respondents were given training on how to use the V-Frog™ software program. Immediately after the treatment, which took about 1.5 hours, the respondents were given the posttest and questionnaire to answer. The contents of the questionnaire involve background information, perceived learning effectiveness and satisfaction questions. A gap of two weeks between the pretest and the posttest was for the purpose of reducing the pretest sensitization threat.

6 Data Analysis

Frequency and proportion were used for descriptive statistics. Independent-samples t-test was used to determine the difference in the pretest, posttest, gain scores, perceived learning effectiveness and satisfaction for accommodators and assimilators.

7 Results

7.1 Distribution of Learners

Out of 232 students, 22 of them did not fully complete all instruments, that is, they were either absent on the day when the pretest or posttest was conducted, or did not return the questionnaire. Hence, only 210 participants were taken into consideration in the analysis. The sample was 42% (88) and 58% (122) in males and females, respectively. As for the learning styles, 57% (119) students were accommodator learners while 43% (91) were assimilator learners. The mean age of the participants was 16 years old.

Table 1. VR knowledge of the students

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Know Nothing	96	45.7	46.2	46.2
	Some Knowledge	85	40.5	40.9	87.0
	Lots of Knowledge	8	3.8	3.8	90.9
	Some Experience	19	9.0	9.1	100.0
	Total	208	99.0	100.0	
Missing	System	2	1.0		
Total		210	100.0		

As shown in Table 1, based on those who had answered this question, almost half of participants, that is, 46.2% have no knowledge about VR, 40.9% have some knowledge, only 3.8% know a lot more about VR and 9.1% have some experiences in using VR.

7.2 Homogeneity of Pretest

Independent-samples t-test showed no statistically significant difference in the pretest scores for accommodator learners (M= 41.57, SD = 20.32 and assimilator learners (M = 45.19, SD = 19.45, t(208) = -1.301, p = 0.195), which inferred that all learners were homogeneous in the existing knowledge of the subject matter. Statistical tests were conducted at the alpha = 0.05 significance level.

7.3 Testing of Hypotheses

Independent-samples t-test was used to analyze the data. The assumptions for this test were performed before it was conducted, and this test was found to be appropriate for employment. Statistical tests were conducted at the alpha = 0.05 significance level. Levene's test was used to test the homogeneity of variances. There was no significant difference in the variance of both groups in the posttest (F = 0.029, p = 0.864), gain scores (F = 0.005, p = 0.946), perceived learning effectiveness (F = 0.000, p =0.991), and satisfaction (F = 0.044, p = 0.834). In other words, the basic assumption of homogeneity of variance was not violated.

7.3.1 Testing of H1

The statistical results did not reject the null hypothesis (p > 0.05). As shown in Table 2, there was no significant difference in the posttest score for accommodator learners [M = 65.05, SD = 15.72] and assimilator learners [M = 66.11, SD = 15.68, t(208) = -0.484, p = 0.629].

Table 2. Mean scores, standard deviation (SD) and t-test of posttest, gain scores, perceived learning effectiveness and satisfaction for accommodator learners (N = 119) and assimilator learners (N = 91)

Variables	Accommodator Mean (SD)	Assimilator Mean (SD)	t	df	*p*-value
Posttest	65.05 (15.72)	66.11 (15.68)	-0.484	208	0.629
Gain Scores	23.48 (19.27)	20.92 (19.26)	0.953	208	0.342
Perceived Learning Effectiveness	3.94 (0.54)	3.93 (0.53)	0.100	208	0.920
Satisfaction	3.97 (0.60)	4.09 (0.57)	-1.443	208	0.151

7.3.2 Testing of H2

The statistical results did not reject the null hypothesis ($p > 0.05$). Non-significant result was found in the gain scores for accommodator learners (M = 23.48, SD = 19.27) and assimilator learners [M = 20.92, SD = 19.26, t(208) = 0.953, $p = 0.342$]. (see Table 2.)

7.3.3 Testing of H3

The statistical results did not reject the null hypothesis ($p > 0.05$). As presented in Table 2, there was no significant difference in the perceived learning effectiveness for accommodator learners (M = 3.94, SD = 0.54) and assimilator learners [M = 3.93, SD = 0.53, t(208) = 0.100, $p = 0.920$].

7.3.4 Testing of H4

The statistical results did not reject the null hypothesis ($p > 0.05$). Non-significant results was found in the perceived satisfaction for accommodator learners (M = 3.97, SD = 0.60) and assimilator learners (M = 4.09, SD = 0.57, t(208) = -1.443, $p = 0.151$]. (see Table 2.)

8 Discussion

In terms of cognitive learning outcomes, there was no significant difference in the performance achievement and the overall improvement in performance between accommodator learners and assimilator learners. This implies that the effects of VR learning on both accommodator learners and assimilator learners were almost equivalent. Indeed, Bell and Foyler [13] have mentioned that, experience - the main feature of VR is of great benefits to all learning styles. In other words, VR could provide support to all elements of Kolb's model. A possible explanation to the findings is the virtual environments that mimic the real world provide concrete experience to the learners. Learners could actively construct knowledge through experiment [15]; experience the consequences as they could actively explore the virtual environment and have the autonomy and control over their own leaning [15, 16]. Moreover, the synthetic replica of objects by the virtual environment would help to concretize and reify ideas. Besides, the instructional material in text and images could provide reflective observation and abstract conceptualization to learners. Thus, the VR learning mode covers all four extreme ends of the information perception continuum and the information processing continuum of Kolb's model. In other words, the VR learning mode supports Kolb's model of experiential learning by providing concrete experience, abstract conceptualization, active experimentation and reflective observation. The findings are consistent with the study of Chen, Toh and Wan [18] in which their VR (guided exploration) mode benefited equally to both accommodator learners and assimilator learners.

Additionally, there was also no significant difference in perceived learning effectiveness and satisfaction between accommodator learners and assimilator learners. In other words, all learners regardless of their learning styles, had a similar perception of the learning quality in the VR-based learning environment and experienced the same level of satisfaction. Based on a 5-point scale with higher score indicating better perception in learning quality and satisfaction, both groups scored approximately four on perceived learning effectiveness and satisfaction. Thus, this indicates both groups have agreed that the VR-based learning environment allowed them to achieve the desirable learning effectiveness in identifying the issue learned, making generalization and conclusions. Likewise, both groups experienced a high level of satisfaction in the VR-based learning environment. The positive emotions generated when learning with VR could be the partial cause as to why both types of learners had a high perception on the affective learning outcomes. Research has shown that positive emotions experienced during learning could improve satisfaction and perception towards learning [28]. The esthetic elements such as colors, layout and graphic illustrations of the VR learning material could be the partial cause of the positive effects on perceived learning effectiveness and satisfaction for both types of learners [4]. In short, VR has appealed positively to the affective and emotional state of the learners irrespective of their learning styles. The high level of perceived learning effectiveness and satisfaction implies that learners irrespective of their learning styles are willing to adopt this technology and thus will have an impact on the success of this technology.

9 Conclusion

This paper has investigated the effects of VR on learners with different learning styles. The findings of this research have important educational implications of VR. Based on our findings, there was no significant difference in the performance achievement, overall improvement in performance, perceived learning effectiveness and satisfaction between accommodator learners and assimilator learners in the VR-based learning environment. This implies that VR provides equivalent cognitive and affective benefits to learners with different learning styles, and it could accommodate individual differences with regard to students' learning styles. These findings have provided evidence on the potential of VR to empower students' learning in secondary classrooms. It is suggested that future studies look into the effects of VR on other student characteristics in which the results would benefit individualized learning.

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