VIRTUAL FIELD TRIP

Virtual Field Trip

Parviz Safadel
David White
Texas Tech University, U.S.A

Abstract

The purpose of the current investigation is to continue validating the Psychometric Properties of the Spatial Ability Self Efficacy Scale (SASES) in virtual Immersive Environments (VIE). Previously, we tailored the SASES to increase the prediction of students' performance and retention in environments with spatial frameworks. Although the results of the study showed high reliability of the Spatial ability self-efficacy scale, a gap remains in our understanding surrounding VIE. The need to investigate the SASES in VIE is immediate. This pilot study investigates the impact of VIE on students SASES through the instructional tutorial, simulation activity, and matching game. A sample of 7 college students was assigned to measure satisfaction and spatial ability. The results of the pilot study showed that students' overall satisfaction for using VIE was very positive, and the amount of the time spent in VIE positively correlated with spatial ability.

1. Introduction

Visualization of 3D models is quite tricky, and it might be more challenging for students with less spatial ability. This inability of students who study specifically in Science, Technology, Engineering, and Math (STEM) fields may cause frustration [1] and, in result, may affect their learning performance and self-efficacy as well.

Although the role of spatial ability factor is crucial in the STEM, still little application of spatial ability can be found in instructional and learning environments [2]. The inability to distinguish and perform in disciplines that require mental visualization may have adverse effects on students' self-efficacy as well [3].

We propose a method that offers a productive environment to respond to the abovementioned problems. It includes cutting edges technology for advancing learning in STEM fields and supports explicitly educational departments to provide intensive teacher development and research on how students learn in such VIE. The goal is to stimulate student curiosity, inquiry, and investigation while encouraging their spatial ability using VIE.

The overall objective of the current study is to see how individuals learn in VIE and whether or not the cognitive and learning styles of individuals may have a different reaction in this environment. Respectively, these characteristics may be considered to design learning environments that consider cognitive load and spatial navigation of individuals. The current research study points explicitly to the following research questions in the VIE study.

H1: Does the instructional design strategy impact the learning outcome gains in VIE?

H2: Does VIE affect student satisfaction, usability, perception, and apprehension toward computer technologies?

H3: Is there an interaction between VIE, spatial ability, and SASES on student memory recall?

2. Literature review

Research shows the roles of simulation in creativity education and how highly interactive virtual environments can enhance students' learning experiences. The researcher found how game-like VIE help to develop a positive learning behavior [4]. Engagement is the primary objective in gamified VIE, and research indicates the importance of this factor [5].

Studies indicate the importance of using VIE by Teachers for their teaching [6]. From Oh and Nussli's research [6], for example, several key benefits can be highlighted, namely social practice, collaborative learning, and increased motivation, especially for tedious topics. These features are all aligned with Bandura's [7] social learning theory. Research in VIE is essential for STEM educators whose discipline requires students' spatial understanding of conceptual models. One example is when biology students use instruction to learn molecular biology concepts and models. Creating a physical model of macromolecules by using mockup models is quite a difficult task when the complexity of a model increases, specifically for students whose cognitive styles favor less spatial ability. However, The VIE environment increases the sense of perception and interactivity and is a unique tool for learning molecular biology, which, on the contrary, is very hard to understand from text-based presentations [8]. Respectively, other researches also show the use of VIE in higher education science classrooms and its positive impact on class learning experiences including an increase in motivation and interactivity [9, 10, 11].

According to situated learning theory, all learning happens in a specific framework [12]. One of the salient features of this theory and its implementation in VIE is the issue of transfer [13]. One of the crucial issues of instruction is the low rate of far transfer created by presentational instruction. That is, students often are unable to apply the learned material to a similar real-world environment. The advantage of using an immersive interface is that by simulation of the real world, the students must attain near transfer to get ready for future learning [14].

The intersection between Learning Science and VIE has been studied vigorously in the past decade, and there is plenty of research indicating the significant use of VIE in education. Few instructional design studies, however, have yet attempted to measure explicitly several variables that are believed, on the theoretical grounds, to play essential roles in the compound relationship between learners and VIE. The primary objective here is to come up with an appropriate instructional design model and a proper formative and summative evaluation that can be used as a model to create instructional material for the immersive or non-immersive environment.

The intellectual merit of the current proposal is to investigate the impact of VIE on student learning performance in an environment with spatial frameworks.

In the last decade, VIE has received a tremendous amount of attention by researchers from different fields such as landscaping, engineering, construction, training, and education, to name a few. The focus of the research mostly was on system design, usability, user satisfaction, and navigation. However, in comparison with other mature multimedia studies in education, such as the theory of multimedia learning these studies are in early stages, and evidence regarding the effectiveness of using VIE is still elusive. In this regard, Researchers should shift their view and consider VIE as a concept rather than mere tool and study its effectiveness based on VIE characteristics and affordances. There is still little evidence that point how individuals learn in this system and whether the cognitive and learning styles of individuals may have a different reaction in this environment. Respectively, instructional designer may consider these characteristics to design learning environments which consider cognitive load and spatial navigation of individuals. VIE mixes reality and fantasy which may be confusing for novice learners and to a certain point disconnecting from real world may not be productive and may cause safety issues. The proposed study establishes the first step in a long-term research program, where replication and expansion of this practice to other areas will produce a longitudinal dataset appropriate for creating instructional design strategies for VIE.

The broader impacts of the current study are implicit in the abovementioned intellectual merit. However, its broader implications fall in the category of a project that integrates research to discover and understand while at the same time promotes teaching and training. The aim is to advance our understanding of VIE as a method of choice in learning environments with spatial frameworks through a conceptual analysis that relates these immersive technologies to the broader study of scientific implication. Such research is essential in achieving instructional design clarity helpful to teaching, training, and learning. For example, to measure the spatial ability of individuals in haptic environments, the standard models used for measuring spatial abilities are not sufficient. New instruments should be developed to measure spatial ability and visualization of individuals in haptic environments. Research as such may contribute to the understanding of the individual's psychomotor using immersive environments. Immersive technology, without a doubt, is central to 21st education and integrating it effectively through research in our educational system will establish a stronger foundation to teach STEM courses.

3. Methodology

The purpose of this study is to examine the effectiveness of the VIE setting which focuses on spatial frameworks such as in STEM fields. In this regard, we developed a Spatial ability self-efficacy test which has been tailored to increase the prediction of students' performance and retention in learning environments that rely heavily on spatial ability [8]. This instrument can be utilized to predict the correlation between students' self-efficacy, spatial ability, and their retention in environments with spatial frameworks such as in STEM fields. Moreover, different instructional design strategies will be tested to determine the effectiveness of each in different VIE such as an instructional tutorial, simulation activity, and matching game to examine our research questions.

3.1. Experimental design

Participants were assigned to the research activities created in VIE. After completing demographics, students completed a self-efficacy test regarding their spatial ability. After that, students answered a 30-item spatial ability test. Right after the spatial ability test, subjects studied a lesson and answered the respective assessments. At the end of the experiment, participants completed the satisfaction questionnaires.

3.2. Content for tutorial

Students were introduced to the structure of Nucleic Acids to recognize that: 1) Deoxyribonucleic acid (DNA) is composed of phosphate, deoxyribose, and four major bases: adenine, guanine, cytosine, and thymine. 2) DNA is polymers of nucleotide subunits. 3) A nucleotide is composed of a phosphate group, a pentose sugar, and one of the four corresponding bases. 4) The backbone of a DNA molecule is a chain of repeating deoxyribose-phosphate units. 5) DNA is composed of two chains in the form of a double helix. 6) In DNA, adenine will only bind with thymine on opposite chains, and guanine will only bind with cytosine on opposite chains.

3.3. Development of VIE

We used different 3D visualization software such as Blender combined with the Unity game engine to create sounds VIE. The VIE is used as our research conditions to examine our research questions

3.4. Design of 3D environments

To create our 3D models and environments, we used the Protein Data Bank (PDB), which is a 3D depository of biological macromolecules such as protein and nucleic acids. We downloaded the PDB files directly to the blender. PDB files can be imported into the blender using ePMV add-ons for blender. Other 3D models used for the Spatial ability test were created in blender software and imported as 3D assets into the Unity game engine.

The Tutorial about DNA structure was primarily created in Adobe Captivate and later imported to the Unity game engine using the Unity UI system. Students could walk around the room or beam themselves to different parts of the environment and interactively engage in the learning process.

Since a game-like VIE help to develop a positive learning behavior [4] and engagement is the primary objective in gamified VIE, and research indicates the importance of this factor [5], we created a game-like simulation to test the retention of students in VIE. The simulation has two phases, mainly easy and challenging.

3.5. Conditions

The VIE contains interactive elements for students who were assigned to our research study for this activity. Students studied the VIE lesson and actively participated while engaging with the content. After completing the experience, participants answered a recognition memory test that challenged their visuospatial memory.

3.6. Participants

For the current pilot study, undergraduate students (N=7) were recruited by offering them course credit.

4. Results

A Chi-square goodness of fit test was conducted to assess student satisfaction, usability, perception, and apprehension toward using VIE. Table 1 shows that students' overall usability and perception for using VIE are very positive.

Preliminary findings of the study include some interesting aspects of using VIE. The graphs shown in Figures 1 and 2 indicate a significant difference in required time and effort to complete the 3 simulation tasks; this was the intended design. Additionally, there appears to be a burgeoning interaction between level 1 and level 2 tasks based on grouping the subjects using a high and low spatial designation (split median). More subjects are needed to verify this finding.

Table 1. Students' overall satisfaction

Usability questionnaire description	Mean/SD	*P* Value
Navigation in the VR program(general)	1.29/0.49	0.0001***
Navigation in the VR program (ease of use)	4.57/0.79	0.0008***
Usability level in using VR test(frustration)	1.29/0.49	0.0001***
Usability level of VR program(frustration)	2.14/1.35	0.0036**
Experiential questionnaire description	Mean/SD	*P* Value
Perception of computer software (problems)	2.57/0.79	0.0714
Perception of VR program (overall)	4.57/0.53	0.0001***
Apprehension level using VR Program (just prior)	3.00/1.15	0.1336
Apprehension level during VR test (frustration)	2.86/1.57	0.1336
Computer software experience (previous)	2.86/1.35	0.0036**
Anticipated potential future uses for VR	4.86/0.38	0.0001***

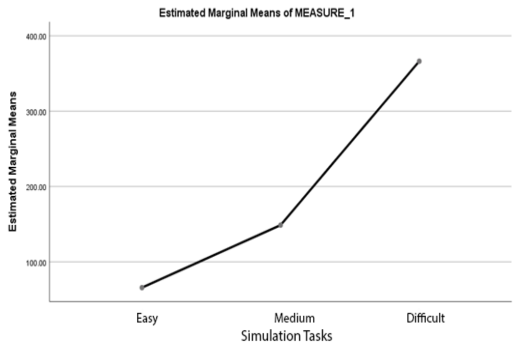

Figure 1. Simulation tasks (time)

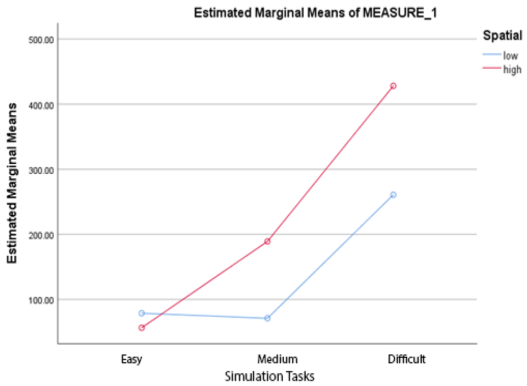

Figure 2. Simulation tasks (spatial)

The preliminary findings for the game task shown in Figure 3 indicate that the task requirements are significantly different when considering the required effort and time needed to complete the tasks. Additionally, there are a within-subjects observed significance that occurs based on the spatial value assignment (Figure 4) of either high or low for subjects (split median). More subjects are needed to verify this finding.

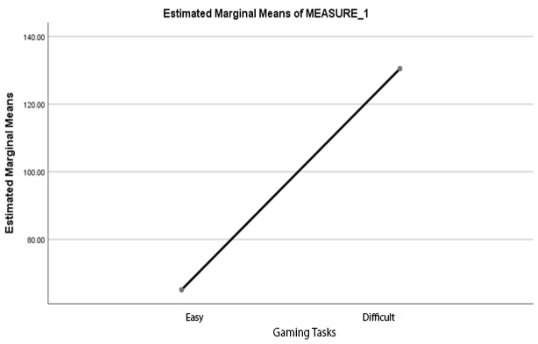

Figure 3. Gaming tasks

Table 2. Tests of within-subjects contrasts for gaming

Source	tasks	df	F	Sig.
tasks	Easy vs. Difficult	1	30.83	.001
tasks* Spatial	Easy vs. Difficult	1	.182	.681
Error (tasks)	Easy vs. Difficult	8		

a. Computed using alpha = .05

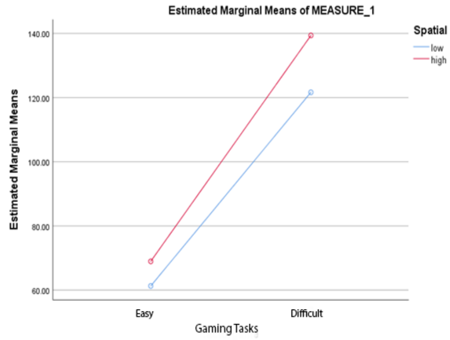

Figure 4. Gaming tasks

We observed (Figure 5) a Pearson r correlation coefficient between the spatial measures and SASES measures of r = .618, and we would like to see if this value will increase with the addition of subject cases.

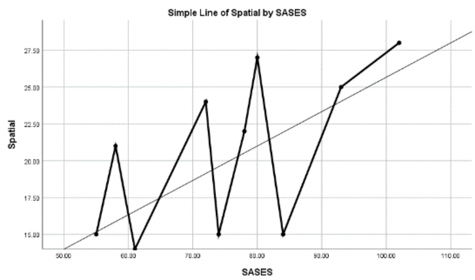

Figure 5. SASES

5. Discussion

Based on the data observations, the aimed instructional design in VIE and the examination of the theory of multimedia learning in connection with the spatial understanding of individuals together is an ongoing interest in this research. As mentioned above, we tailored a SASES to predict students' retention in environments that have spatial frameworks. However, we needed to examine this scale in the VIE to see if the scale measures what it is supposed to measure. Concurrently, we developed research activities specifically for VIE, such as games, simulation, and tutorials to measure different factors that might have confound effect on individuals learning such as time, mood (environmental/personal), and motivations.

Moreover, because of the complex behavior of individuals in VIEs, we would like to integrate into our actual upcoming research an eye-tracking collection to obtain individual behaviors through his/her gaze using VIE. Through this process, we will find insights about individuals' cognitive and attentional processes as well.

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