Student Perceptions and Initial Response to using Virtual Reality for Construction Education

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The use of immersive Virtual Reality (VR) as a means of entertainment has drastically accelerated over the last few years because of the increase availability in affordable technology. Its use in the design and construction industries has also rose and has served as a powerful visualization tool for clients to understand space. This study looks to examine the perceptions of construction management students on the use of Head Mounted Display (HMD) VR in the classroom as a teaching aid. The study allowed students to interact with a developed virtual environment utilizing Samsung GearVR headsets and Samsung S7 devices. A pre/post survey was used to document students' perceptions before and after exploring the environment. The post survey was also used to document where students might see this technology applied within their curriculum. Overall the students who participated were open to the incorporation of the technology into the curriculum and rated their experience within the HMD-VR environment as positive. This paper presents an overview of this study and how the environment was developed and then details the student survey results. Recommendations for future content development and some instructor observations are also included.

Key Words: Virtual Reality, Construction Education, Undergraduate Education, Construction Methods

Introduction

Over the past few years, the use of Virtual Reality (VR) and Head Mounted Display (HMD) to view virtual environments has increased with the technology producing a better quality experience at a lower price. Beyond entertainment, this technology can impact the building industry. This research is looking at what impact the HMD-VR environments could have in a construction management curriculum.

VR in Design and Construction

Within design, VR has allowed for a very powerful visualization tool that research suggests can simulate real life reactions to the simulated environment. Immersive virtual environments can provide a similar sense of presence and understanding of space as physical mock-ups (Heydarian, et. al, 2014). Simulated immersive environments were also used for hazard response of building occupants within an apartment fire building suggesting that a similar emotional response can be gained through the simulation as if it was a real life event (Zou et.al, 2016).

VR has been used in construction for training trade workers who work at height with some promising results for using commodity technology and software to limit the cost and setup (Bosch, et. al, 2016). It has also been used to explore construction safety and situational awareness of workers on the ground while completing tasks around heavy machinery (Hilfert, et.al, 2016). The research utilized modern, low-cost head mounted display hardware and a first person simulation. The results show possible improvement in rapid hazard evaluation and learning.

In addition, 3D real-time user visualizations within a simulated virtual reality environment allowed for workers to perform hands-on collaborative tasks from individual viewpoints such as operating a crane and directing a blind lift (Fang and Teizer, 2014).

VR in Education

Through an analysis of case studies, Curcio et.al (2016) identified that there was evidence to suggest that students who use VR simulations for learning have increased motivation, engagement, and critical thinking skills. The study also found that VR positively supports knowledge transfer. Other research shows that the use of virtual games in education has promise in terms of long-term knowledge retention (Cheng, et. al, 2015). Jou and Wang (2013) found that virtual reality learning environments can help students gain efficiency with technical skills. Merchant et.al (2014) determined that open unstructured virtual spaces that allow for exploration and flexibility of learning by the student were more effective, especially when connected to knowledge-based, abilities-based, or skill-based measures of learning.

Within education, related to engineering and construction, VR was used in both a CAVE and immersive headset environment as a supplemental teaching aid within a structures design course. This study resulted in an increased of student understanding of structural concepts (Fogarty, et.al, 2015). Within construction, VR has been utilized to help teach students about construction safety hazards and how they related to construction methods (Pedro, et.al, 2016). Within this research it was determined that the innovative medium for experiential learning allowed for an improvement of hazard identification, transferring of safety knowledge, and engagement of students.

Research Goals

This research aims at developing a better understanding of how HMD-VR can be used to supplement construction education. In doing so, students are asked to participate in studies to identify how they react to different types of virtual environments as phase one of the research. Phase two (future research step), is to develop content and test the effects on learning course material when HMD-VR is applied as a learning aid.

The purpose of this initial study was to:

1. Explore how students respond to the use of HMD-VR in order to gain a high-level understanding of how the students may benefit from the use of the technology in the classroom
2. Identify where HMD-VR simulations may be appropriately used in the construction curriculum based on student responses and instructor observation.

To complete this study a simple virtual environment was developed and deployed on a Samsung GearVR 2nd Generation headset that was run using a Samsung Galaxy S7 smart phone (Samsung, 2017). Once the environment was active, students were recruited to take part in an Institution Review Board (IRB) approved quasi-experimental study where they were asked to participate in a pre and post intervention survey. The intervention was the actual use of the technology to navigate around the virtual environment. The goal of the pre-post surveys was to:

- Document how the students' perceptions changed from before to after using the technology
- Identify the benefits students perceive of the potential implementation of the technology within the curriculum as a learning aid
- Determine areas of the curriculum they may be suitable for HMD-VR content development
- Identify any discomforts the students may have experienced while using the technology

The results of this survey are discussed in this paper.

Virtual Environment Development

The virtual environment includes a simple model of a one-story home on a slab foundation that is in the framing stage (Figure 1). For ease of incorporating the model int Unity, the virtual environment development software, it was developed in SketchUp (Trimble, 2017). Other types of models can be imported into the Unity development environment, however a SketchUp model back-saved as Version 8 or lower can be directly inserted as an asset without the need for any intermediate model processing steps. For the ease of getting the virtual environment to the point of deployment on the headset, the SketchUp model was chosen. With the SketchUp model completed, the virtual environment was developed in Unity (Unity, 2017). Unity is an application development software that allow for the development of virtual environments that can be implemented on different hardware platforms. For the purposes of this research, the Android based Samsung Galaxy S7 and GearVR are used to take advantage of Oculus developer kits that allow for easier incorporation of navigation and controls for an immersive VR experience. The GearVR also represents a non-tethered, mobile HMD that is relatively inexpensive which could lead to a wider use within education than tethered (hard wired to a computer) HMDs. The GearVR platform is powered by the Oculus immersive VR technology and is compatible with most Oculus Rift development applications. Unity also allows for the direct viewing of the environment in the Oculus Rift during the development process. This allows for quick feedback on the development during the testing phase before the application is built. The overall development process for the virtual environment is shown in Figure 2.

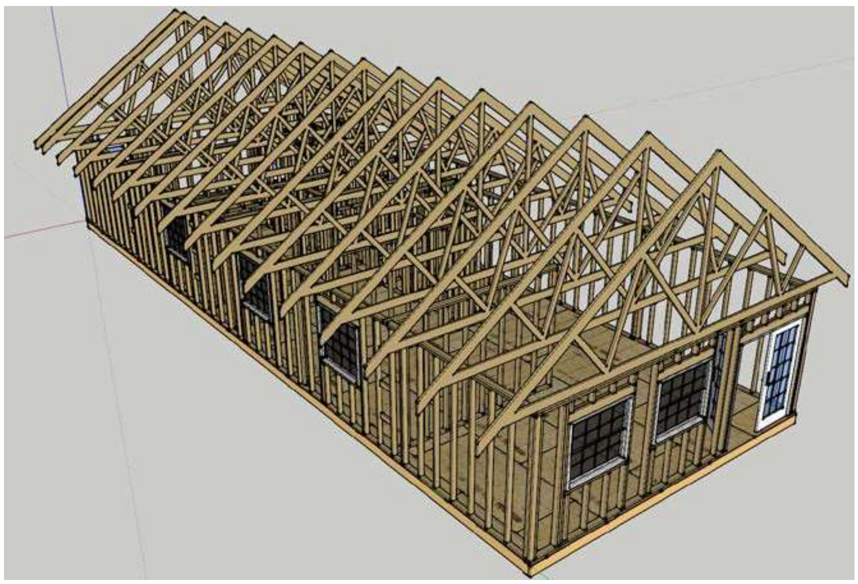

Figure 1: Wood framed house SketchUp model for virtual environment

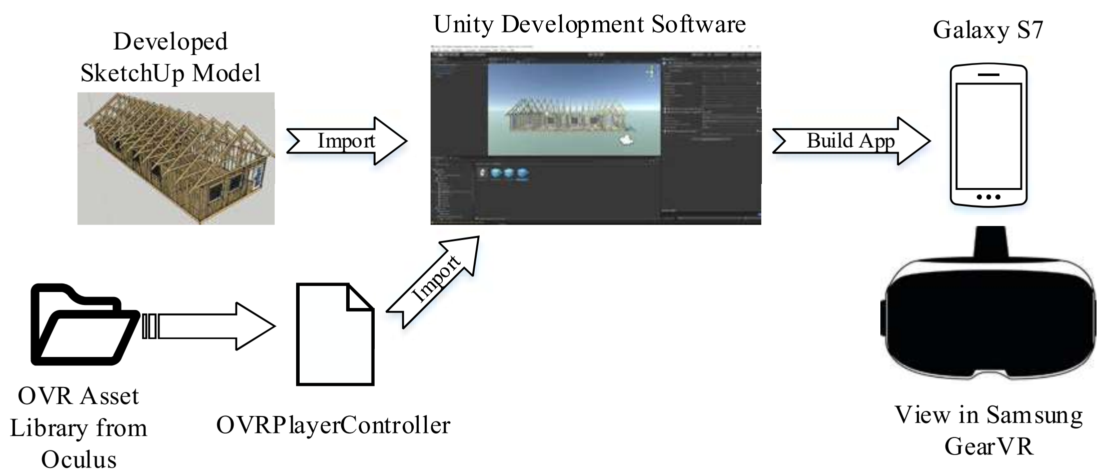

Figure 2: Virtual environment development process

Within the Unity environment, the SketchUp model was imported as an asset. A simple ground, background, and lighting design were added directly in Unity. The OVR Asset Library from Oculus standard development kit (Oculus, 2017) was utilized to prepare the environment for deployment on the GearVR. From the OVR library, the OVRPlayerController Prefab was used as a basis for navigation. This controller prefab allows for the incorporation of an Xbox style controller. It also contains the coding for head tracking within the VR environment. This allows the user to turn their head in the X, Y, and Z-axes to look around the environment in 360 degrees on each axis.

During development, the environment was tested utilizing the Oculus Rift in beta test mode directly within Unity. After development, the application was built for deployment on the smart phone and executable application. The Galaxy S7 was used to power the GearVR since at time of development it offered the best balance of processing power and pixel density to allow for a quality user experience. Once the app is opened on the phone a message appears to insert it into the GearVR. Once the phone is connected to the GearVR the environment is active for the user. The finished environment allowed for the user to navigate through the model with the use of an Xbox style controller. The environment also included head tracking which allowed the user to turn their head in the X, Y, and Z-axis to look around the environment in 360 degrees in all axes.

Student Survey and VR Interaction

Students from the Construction Science and Management (CSM) program and identified as CSM Majors were recruited to participate in the study utilizing pre-post test survey analysis. Participation was optional and open to any undergraduate student within the major. The process that each of the students took in completing the study included:

1. *Pre-VR Survey* – Each student completed a survey before experiencing the environment. The survey included questions on past use of video games and VR, basic demographics, and areas that they may see the technology used in the curriculum.
2. *VR Environment Use: Intervention* – Each student was given a brief tutorial on navigating through the environment with the Xbox style game controller and focusing the headset. The students were advised that if they felt discomfort such a nausea, eye strain, or dizziness (all common side effects of VR use) that they should stop immediately. Most students spent 5-8 minutes within the environment. Any longer or extended use can lead to discomfort and side effects.
3. *Post-VR Survey* – Each student was asked to complete a survey after experiencing the VR environment. This survey included Likert-scale questions on their experience and any discomforts that they felt. Qualitative free responses were also received to allow students to expand on their perceptions. Lastly, open response questions were asked to document how the students could see VR used within the curriculum and gain feedback about the general user experience.

Study Demographics and Pre-Survey Results

Overall, 27 students completed the study and survey out of 110 students in the classes that were recruited from resulting in a 24% response rate. The breakdown of these students consists of 7 Freshman, 14 Sophomores, 3 Juniors, and 2 Seniors.

Of the study participants all but two identified playing console video games (such as Xbox or PlayStation) for some time, the total breakdown is shown in Table 1.

When it came to immersive HMD-VR experiences 16 (60%) had no prior experience with HMD-VR, 5 (19%) had used the Oculus Rift, 4 (15%) have used the Samsung GearVR, 1 (3%) had used Google Cardboard, and 1 (3%) had used a system but could not remember which one. Of the participants who had prior use with immersive HMD-VR, 6 used it for gaming, 2 to view videos, 2 for interior building walkthroughs, 1 for real estate home tours, and 1 for virtual combat training.

Table 1

Prior Video Game Experience

Experience with Console Video Games	Responses
Do not play on any regular basis	2 (7%)
Not very often, intermediately – socially – less than 2 hours a week on general	12 (44%)
2-4 hours a week, but not daily	6 (22%)
5-10 hours a week	3 (11%)
More than 10 hours a week, but not daily	2 (7%)
Daily, less than 2 hours	2 (7%)

Post-survey Summary Results

Once students completed the use of the HMD-VR simulation they were given a post-survey. The post-survey first included Likert-scale questions about the model's visual appearance in terms of the simulation's ability to allow for (1) an understanding of the spatial qualities of the structure, (2) distinguishing what the materials are made of, and (3) an understanding of the components of construction. A 1 to 5 scale for agreement was used, with 5 meaning greater agreement. The results for these questions are shown in Table 2.

Table 2

Response to the visual appearance of the HMD-VR experience

				Frequency				
Question	Average	Mode	Range	1	2	3	4	5
1	4.70	5	4 to 5	0	0	0	8	19
2	4.70	5	4 to 5	0	0	0	8	19
3	4.48	5	3 to 5	0	0	2	10	15

Additional open response comments received about the visual appearance and HMD-VR experience include (responses are paraphrased: number in parenthesis represents number of mentions in responses):

- Helped to understand the feeling of space, not just characteristics of space seen on paper (6)
- Interactivity – personalized view of the model (3)
- Allowed a better understanding of the parts of the building (3)
- Allowed for quick understanding of the entire space (2)
- Allowed for a better understanding of the scale of space (1)

The second part of the survey captured data related to the usability and wayfinding of the environment. It is important that if a tool is developed for educational use that it is user friendly and not intimidating. If students were to get frustrated while using the technology or have a bad experience with technology that can influence their motivation in using new technology for learning (Granito and Chernobilsky, 2012). Concerning the user friendliness that was felt while navigating the environment, 17 (63%) responded Very Easy (5 on the 1-5 scale) and 10 (37%) said Easy (4 on the 1-5 scale). When considering the ease of wayfinding through the model: 18 (67%) said very easy (5 of 5) and 9 (33%) said easy (4 of 5). Lastly, considering the visual clarity of the model: 6 (22%) students said the model was very clear; 19 (70%) said it was clear, that some objects/textures were unclear, but the model was understandable; and 2 (8%) said clear enough to understand the intent of the model. Open responses that documented further explanation of students' thoughts concerning overall usability of the environment and used to inform new iterations of the simulation.

The third part of the post-survey included 5-point Likert-scale questions to identify the level of comfort (physically, physiologically, and physiologically) the participants experienced while using the HMD during the study. Physical discomfort was defined by wearing the HMD with a ranking of: 1) Comfortable, no different then wearing ski goggles to 5) they were heavy and difficult to stay in place. The distributed response were 16 (59%) at 1, 6 (22%) at 2, 2 (8%) at 3, 1 (4%) at 4, and 2 (8%) selected 5 stating they had difficulty keeping the headset in place. This indicates that the weight and way the technology is strapped around the user's head may be a concern.

Physiological comfort dealt with the feeling of nausea, motion sickness, eyestrain, and vertigo. When caused by the use of technology, such as an HMD, these are symptoms of cyber-sickness. Cyber-sickness is similar to motion sickness and caused by the use of a virtual environment stimulating the brain into feeling as if it is in motion (LaViola, 2000). Causes include unclear images, over focusing the headset, poor navigation, slow processing performance and movement lag. Mobile, non-tethered HMD devices like the GearVR can cause a lag when user move around the environment because of the lower processing speed on the mobile device than a tethered device connected to a high powered computer. 12 (44%) said that the movement lag was not noticeable, 10 (37%) said it was noticeable but not distracting, 2 (8%) were neutral on the issue, and 3 (11%) said that movement lag was a very noticeable and distracted a little. It is important to keep the size of the environment within the processing power of the device being used. More complex environments take more time to render and thus can increase the experience of movement lag. With respect to eyestrain: 14 (52%) respondents said they did not experience any eyestrain, 12 (44%) said a slight discomfort was caused by eyestrain, 1 (4%) said they experience moderate discomfort with eyestrain, no one reported a severe discomfort that prevented finishing the simulation. With respect to vertigo, change in balance, or difficult in maintaining balance: 20 (74%) said not at all, 3 (11%) claimed slight discomfort, 3 (11%) said moderate discomfort, and 1 (4%) felt it to the extent that they had to stop using the environment.

Respondents were allowed an open response to further explain any discomforts they may have experienced. These comments included (responses are paraphrased: number in parenthesis represents number of mentions in responses):

- Nausea when moving head and controls at the same time (1)
- Nausea in general – during the experience (3)
- A little uneasy after completing the experience (2)
- Eyestrain towards the end of the experience, length of time in environment (2)
- Dizzy and disoriented quickly (1)
- Discomfort towards the end of use (1)
- Screen was bright and caused discomfort (1)
- When moving too fast, felt like losing balance (1)

When asked how comfortable they felt with their vision occluded within the HMD if they were to use it in front of other students, on a scale of 1-5 with 5 being very comfortable and 1 being not comfortable at all, the average rating was a 4.35 with a distribution of 4 (15%) ranking a 3, 9 (33%) ranking a 4, and 14 (52%) ranking a 5. The question was asked because there was anecdotal concern that people would be paranoid and self-conscience if they could not see others while being seen or have a fear of others doing something while they were vulnerable. This may play into why some of the those who did not participate chose to do so as the testing was often done in small groups of up to five students at a time. However, when the question was if they would feel safe using HMD-VR in a room with other people only 16 (60%) were comfortable or very comfortable with 7 (26%) saying very uncomfortable, 2 (8%) uncomfortable, and 2 (8%) unsure. If HMD-VR was to be used as supplement to the classroom, it may be beneficial to allow the technology to be used outside of the classroom. The instructor would need to be aware of this if it was a required activity.

When asked does the use of new technology, such as HMD-VR, for education cause you any anxiety the respondents all but one who stated they were unsure were either comfortable or very comfortable with no one stating that they experienced major anxiety for using and exploring the new technologies. Lastly, when asked to what extent the simulation allowed them to have a sense of presence within the virtual environment: 1 (4%) said slightly, 5 (18%) said moderately, 12 (44%) said well, and 9 (33%) said very well.

Discussion and Conclusion

One of the last questions that the students were asked in both surveys is where they would recommend the use of Immersive HMD-VR in the classroom. Table 3 shows the responses broken up by the pre and post survey.

Table 3

Student Recommendations for Use of Immersive HMD-VR in the Curriculum

Area of Use	Pre-Survey Responses	Post-Survey Responses
Building Visualization	26	
Understanding Construction Processes	8	
Hands on Building Science Experimentation	1	
Understanding Assembly of Components	9	13
Interactive In-Classroom Explorations of Building Systems	2	5
Spatial Understanding/Scale of Space	1	
Virtual Site Visits		4
Structures of multi-story buildings, complex connections		4
As a supplement to plan reading		3
Reviewing codes		1
Understanding site constraints, laydown, planning of site		1
Project management classes – punchlist review simulation		1

One of the biggest issues with using this technology in the classroom is not the expense and availability but the lack of content to use for educational purposes. There is a need to develop more content for using this technology. The students seem receptive to the idea of its use; however without a bank of content to implement into the classwork the technology's use will remain limited.

As part of future research, based on the input from the students, visualization content is planned to be developed for a materials and methods course to demonstrate to students the different components and assemblies of the building and how they can expect to see the materials put together on site. Once this is completed, learning gain analysis could be conducted to study the actual effectiveness of the technology on learning. The actual development and usability of the environment will need to be kept in consideration for this study.

Some limitations to the study are the number of students and distribution of the students throughout the years of the program. The recommendations are based around the curriculum that the students who participate in the study already had exposure to. If there were more upper level students involved in the initial study, the possibility of additional or more diverse recommendations could be possible. The study can be expanded to target students who are completing or who have recently completed the program to gain better incite from a total curriculum perspective.

Overall, the students were open and receptive to the technology. Many thought it was a very interactive method for them to explore content of what they were learning in class. Careful consideration needs to be given to how long students are using the technology as extended use can lead to more side effects. Consideration also has to be given to where the students are allowed to use the technology as some of them do not feel comfortable when using them in front of other students in a large group.

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