How Virtual Reality Impacts the Landscape Architecture Design Process during the Phases of Analysis and Concept Development at the Master Planning Scale

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Abstract: Virtual reality (VR) can offer many benefits for designers. In the field of landscape architecture, the technology is primarily being used as a tool for design review in the late stages of the design process, yet many of the benefits that make VR valuable in the later stages of the design process suggest that VR may be equally valuable when used in earlier stages such as analysis and concept development. This research examined incorporating VR into the design phases of analysis and concept development, and integrated its use with traditional landscape architecture methods to measure its impacts on a large-scale master planning project. This research explores the advantages and limitations of VR and suggests a positive outlook for VR as a design tool.

Keywords: Virtual reality, design process, immersive design

1 Introduction

Virtual reality (VR) provides visual and spatial advantages that potentially make it a powerful tool for designers. It can provide designers with an improved understanding of design decisions and presents an immersed spatial experience that is different from traditional hand and digital methods of representation. While significant research has been conducted into the use of VR as a visualization tool, research into the efficacy of applying VR to early stages of the design process is still emergent. This study contributes to the understanding of the impact of VR on the design creation process through an analysis of a student project in the VIVID research lab at Utah State University, which was to develop a master plan and town center design for a mountain resort community. VR was a primary design tool used from the earliest stages of design through the development of a final conceptual plan.

2 Literature Review

Virtual reality is a visualization tool with the potential to significantly alter the way that designers and clients create and experience design solutions. TUFTE et al. (1990) describes visualization as a visual medium for clarifying complex data in a way that has substantial advantages over the written word or voice alone. The visual sense is the dominant component of human sensory perception (BRUCE et al. 1996, ROSE 2012), and work on visualization supports expanding the visual sense and incorporating all types of representations across different fields and disciplines (HANSEN & MACHIN 2013, VALIELA 2009, WARE 2013). Along with having a dominant visual sensory perception, the human brain is wired for spatial thinking (GERSMEHL & GERSMEHL 2007). For landscape planners and architects, spatial thinking and

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the communication of design concepts in a spatial context is an essential skill. VR would appear to be ideally suited to assist designers by providing a mechanism that is highly visual and creates an inherently spatial environment.

VR is a digital environment that convinces the mind of the user, through visual and other sensory inputs, that they have entered an artificial world (CASTRONOVO et al. 2013) This type of visualization is valuable to researchers and designers by providing a mechanism to more closely represent and understand the complexities of the landscape (HORNE & THOMPSON 2008). In this study, we examine the use of immersive VR, which is a device that completely immerses the user visually, and sometimes via additional sensory inputs (SLATER & USOH 1993). Immersive VR is an active experience, and the user is able to manipulate the virtual environment (GRAU 2003).

VR has been used in design education for several decades, most notably as semi-immersive VR theatres (frequently referred to as CAVE systems), but the majority of VR-adoption in the design fields has occurred in the late stages of the design process as a review mechanism. Consequently, the majority of research has described the use of VR as a largely passive viewing platform to visualize, rather than create. PORTMAN et al. (2015) analysed the current VR research and found the majority of research focused on passive visualization. WANG et al. (2018) analysed conference presentations that discussed VR in the field of engineering construction and found that nearly 50 % used it solely to visualize design proposals. In a similar analysis, DE FREITAS & RUSCHEL (2013) determined that nearly all use of VR in design was as a visual evaluation mechanism.

Despite VR being largely limited to use late in the design process, researchers have identified several benefits. Immersion is a primary benefit of VR. Immersion is particularly effective for evaluating designs because the wide field of view provides a more realistic viewing experience (CASTRONOVO et al. 2013). Design creation becomes a process experienced through movement and interaction that parallels real world familiarity (DUNSTON et al. 2011). However, there has also been criticism that VR separates the designer from the physical site. This separation, combined with the immersive nature of VR may lead the viewer to make incorrect conclusions about the site (LANGE 2011).

Improved spatial awareness is another identified benefit (CASTRONOVO et al. 2013, RAHIMIAN & IBRAHMI 2011, PORTMAN et al. 2015). In a study using 360 video and immersive VR, students had sufficient spatial understanding of a site from a VR experience to create an accurate site inventory and rudimentary analysis (GEORGE, 2016). However, GEORGE (2016) found that small details were sometimes missed, which supports the conclusion of BULLINGER et al. (2010) that the spatial experience provided by VR may be insufficient in itself to provide for detailed evaluations.

GU et al. (2011) demonstrated that VR could be effectively used to collaborate and DE FREITAS & RUSCHEL (2013) identified increased understanding and communication in collaboration. However, research by GEORGE et al. (2017) found that students had difficulty collaborating in VR because students outside of VR experienced the design differently.

Advancements in recent years have begun to overcome some of the limitations. As VR has become a financially feasible option adoption has grown, and a 2018 ASLA survey reported that 82% of firms have adopted or intend to adopt VR in the near future (GEORGE & SUMMERLIN 2018). During the last few decades, digital landscape representations using VR have advanced from simplistic, static representations (PITTMAN, 1992), to extremely realistic visualizations that allow exploration with real time movement and multiple spatial and temporal scales (GHADIRIAN & BISHOP 2008).

Recent research has begun to explore the use of VR as a design creation tool, and initial findings suggests the medium holds promise (GEORGE et al. 2017, LOMBARDO 2018). CHAMBERLAIN (2015) utilized a gaming engine to create hypothetical urban landscapes to help students understand design principles. GEORGE et al. (2017) demonstrated that VR can be an effective means for developing design concepts on a small site. SLEIPNESS & GEORGE (2017) found that students could rapidly prototype designs in VR more effectively than using computer-modeling software and that they were particularly aware of the spatial impacts of their decisions. Based on the demonstrated value that VR can provide we believe that VR can be successfully used to carry out more robust design activities on larger sites.

3 Methods

The research was conducted with a student design team consisting of ten participants, five females and five males. The class distribution of the design team consisted of two graduate students in their first year and eight undergraduates; two fourth year, one third year, three second year, and two first year. The project was part of a department-wide charrette; a four-day intensive project. The charrette involved planning for a mountain community with an existing ski resort, and various teams covered different regional topics. The ski resort village master planning team was analyzed in this research and was tasked with developing a concept plan of a new village within the resort. The team used a combination of VR and traditional design methods and tested the impacts of integrating VR into the landscape architecture design process.

Several preparatory steps were required to facilitate the analysis and design in the study. Accurate three-dimensional site models were needed to serve as basemaps within VR. This enabled students to virtually visit, interact with, and design on the site as if they were there, as well as understand the regional context in 3D. Two 3D models were created. The first was a regional model that included a 20-mile radius of 3D terrain in order to include and visualize surrounding biophysical relationships such as watersheds and vegetation. This was created using Google Earth to import terrain data from the focus area into SketchUp. This model had comparatively low resolution but provided valuable regional and elevation context to understand the relationship of the site to the surrounding mountains and valleys.

The second model was a detailed 3D terrain model of the project site and immediately surrounding mountain terrain. This model was created using a DJI Mavic Pro drone and Pix4D photogrammetry software. For each mission, the drone flew a grid pattern 250 feet above the ground taking pictures along the nadir line, with an image overlap of seventy five percent. Twenty drone flights and approximately 8,000 images were collected to cover the site. These images were then processed in Pix4D to create a point cloud and 3D mesh. This resulted in a detailed 3D terrain and vegetation model of 900 acres of montane landscape. This preparation process took several days to complete, but yielded a detailed site model and contour data valuable both in and out of VR.

Apart from those already listed, the hardware and software used for this project consisted of a Puget Systems PC with a high-performance CPU and GPU, an HTC Vive VR platform, and Google Tilt Brush VR software. The 3D terrain models from Sketchup and Pix4D were imported into Tilt Brush to be used as backdrop elements the team could design on. While the team primarily used VR to conduct the site analysis and develop design concepts, traditional design methods of 2D basemaps and trace paper were used outside of VR. A large television (43”) was mounted on the wall so that students outside the VR headset were able to see what the designer in VR was creating. All the students on the team worked interchangeably between the two methods for four consecutive days.

Four data collection rounds were used. In rounds 1 and 2, surveys were sent to the participants at the end of the first and second day of the project to collect preliminary user feedback data. These surveys consisted of five questions and covered topics such as how much time they spent inside VR, what were the benefits that they experienced using VR, and what were the challenges that they experienced using VR. Round 3 data collection occurred at the end of day four and included additional survey questions about students’ experience using VR through both open-ended response and rating-scale questions. Round 4 data was collected during a focus group held several days after the last day of the project, to provide students time to reflect upon their experience, and consisted of open-ended question prompts which were discussed by the group. Examples of questions that were asked in the focus group included, how long did it take you to feel comfortable using VR, how effective was communicating designs ideas in VR, and what about collaboration worked and did not work in VR.

4 Results

In Round 1, 6 of the 10 participants responded to the survey of quantitative and qualitative questions. In Round 2, 3 participants responded, which was lower than anticipated and is a limitation of this research. All 10 participants responded in Round 3. Finally, in Round 4, 9 of the 10 participants were present for the focus group. 171 open-ended responses were received. The means of the rating-scale responses were calculated, and the open response questions were coded, identifying fourteen codes (Figure 1). This process produced 214 coded comments. As an example of the coding process, in response to the question “do you feel that VR allowed you to effectively communicate your ideas?” a participant responded: “It was great for saying things graphically instead of with words, which is often hard for me”. This comment was coded as improved self-expression and improved communication of ideas.

The code most mentioned by participants was improved understanding of a design through immersion. Students reported that at first it was challenging to think and design in VR because it was different than their usual process, but after a brief learning curve they reported they had a better understanding of the spaces that they were creating.

Verbal team collaboration was found to be more difficult with one designer in VR while the rest of the team is not. However, visual communication and sharing of ideas with a team was found to be very effective.

Working in VR impacted the students’ design process in several ways. Students reported that they were more aware of the three-dimensional nature of their designs. They also noted that they were better able to express their design ideas and share those concepts with other students. Overall, students responded positively to using VR in the design process and would use it again in the future.

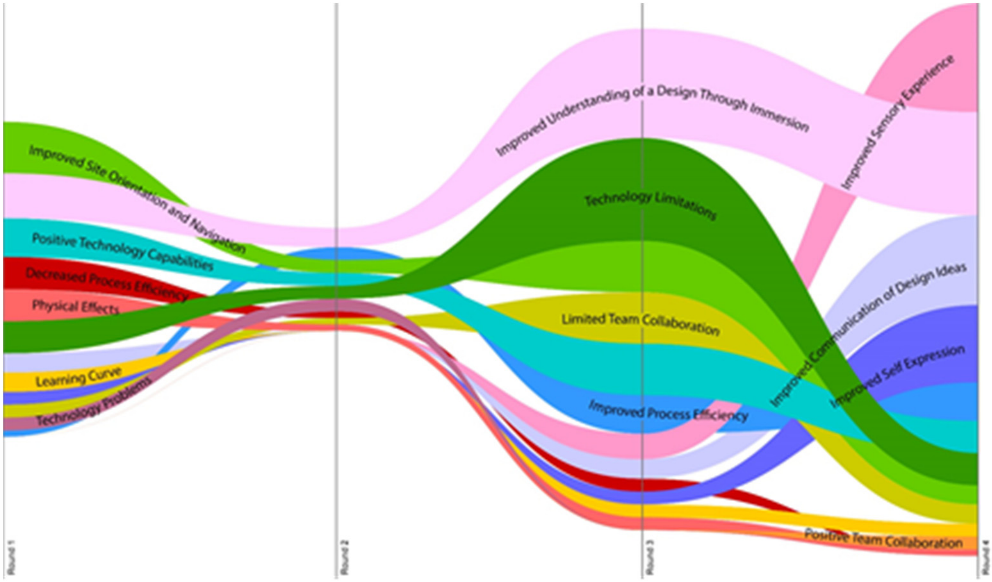

Fig. 1: Variation in code frequency across all four rounds

5 Discussion

The results of the codes from figure 1 suggest an overall positive outlook for the use VR as an analysis and design tool in landscape architecture, however limitations were also apparent. Several codes discussed frequently in the initial rounds tapered off in the following rounds, notably physical effects and technology problems. Several students experienced dizziness in the first round, but that seemed to not persist in the following rounds as their bodies adjusted. One of the ten students reported nausea and limited time in VR for the remainder of the project as a result. Some confusion with the technology occurred at the beginning, but decreased later. Learning curve also showed overall decreasing trends but with a correlation that is slightly less clear. This might be explained by a student's comment who stated, "The basic controls were easy to learn and intuitive, but I am still not completely comfortable with the more advanced controls." This suggests a low bar to entry in using VR, but that it will take more time to become fully competent.

Decreased process efficiency also declined in frequency over the course of the project. Many of these comments talked about how sketching in VR was taking them slightly longer than in 2D. This might be tied to the learning curve limiting speed, but more research is needed to compare the efficiency of VR and 2D workflows and the quality of their outcomes. While this code was mentioned several times, increased process efficiency was mentioned substantially more than decreased process efficiency. Many of the student's comments in this code expressed thoughts about the fast and efficient communication of designs, such as one student who commented that VR "made it quicker to understand and design." This suggests an overall increase in the efficiency of the design process through integrating VR.

The *positive* and *limited technology capabilities* of VR provide an interesting comparison, and these codes appeared in similar numbers throughout all the rounds. Student comments suggest that there were many positive capabilities, such as allowing them to experience the site as if they were there and the ability to interact with their design. Regarding limited capabilities, some students expressed that while Tilt Brush was useful for basic form giving, they felt limited in further refining their concepts and wanted specific tools unavailable in Tilt Brush. Specific tools and abilities that they felt limited without were precision measuring instruments and more detailed surface creation tools. This is important to note because Tilt Brush is primarily designed for artists, and while other programs exist that offer more technical tools, they also come with a steeper learning curve and larger price tag. This contributed to why Tilt Brush was chosen for this research as there was not a VR program at the time that provided an interface and toolset that would support the design approach and scale needed for the project. Such programs may be available in the near future, but for now it must be acknowledged that technology limitations exist for landscape architects using VR.

Collaboration is another set of codes that had both positive and negative responses. Unlike the technology capabilities, this set of codes was heavily skewed towards the negative, and students' responses show that it was challenging at times to work as a group to make modifications to a design. This resulted in students becoming frustrated as they tried to verbally describe what their intent was. This proved to be a limitation throughout the project and confirms the findings of George et al. (2017). However, Likert scale responses to the question "My team could collaborate effectively using VR" resulted in a mean response of 6.2 out of 7 (7 being 'strongly agree' and 1 being 'strongly disagree').

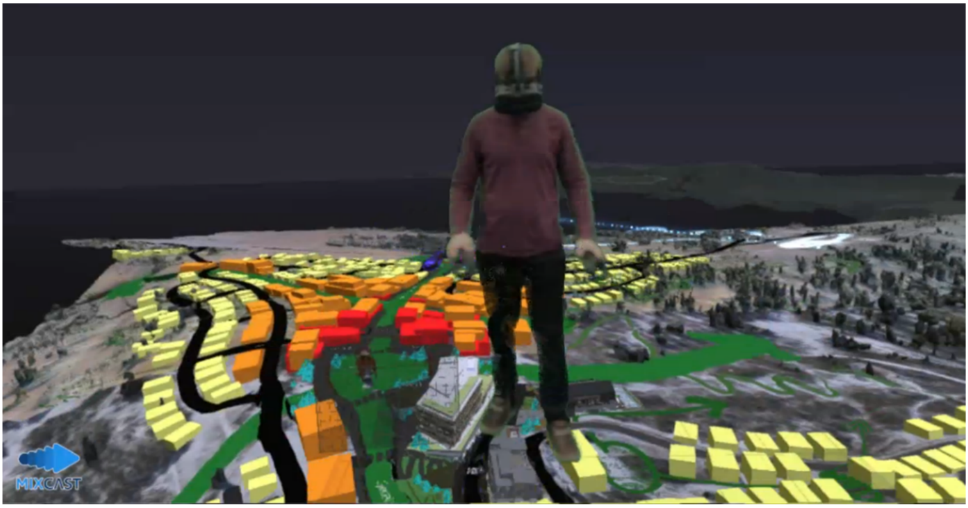

Fig. 2: Student experience within the VR environment

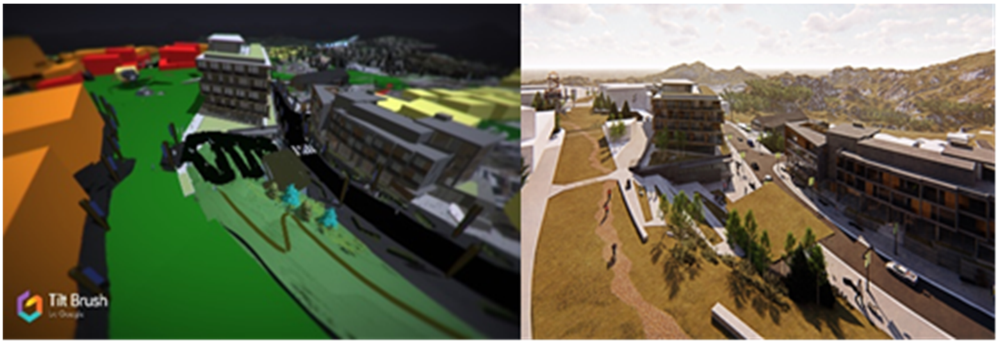

Fig. 3: VR design (left) and final rendering of proposal created with Rhino and Lumion

The coded comments and scale responses for this topic seemingly disagree with each other, and this might be explained by looking at a related code. Improved communication of ideas is a similar code to collaboration, but responses in this category specifically reference visually showing others an idea and their ability to quickly understand it. This code was high during the last two rounds and many of the students talked about how they were able to more quickly and easily share their design. One student commented, "It was great for saying things graphically instead of with words, which is often hard for me." The word 'visual' is also present in many of the comments in this category. This highlights the difference between verbal and visual communication and collaboration. These results suggest that verbal communication and collaboration is hindered in VR, while visual is improved.

The remainder of the codes were the categories of improved site orientation and navigation, improved understanding of a design through immersion, improved self-expression, and improved sensory experiences. These four codes all scored highly overall and suggest important benefits that VR can bring to the design process. These findings support the conclusions of Castronovo et al. (2013) and others. The rating-scales in Figure 4 show that VR made students more aware of the three-dimensional character of their designs, improved their ability to visualize their designs, and altered their approach to design. Figure 4 suggests that students better understood spatial components of their designs and were able to interact with their designs better in VR than traditional methods. Students also marginally favored VR for developing a concept and refining a design over traditional methods. Related student comments include, "it took less mental effort," "it helps you remember what is on site and you see things that trigger your memory of what you saw and experienced when you were at the site," and "you can understand the energy of a design and how it feels."

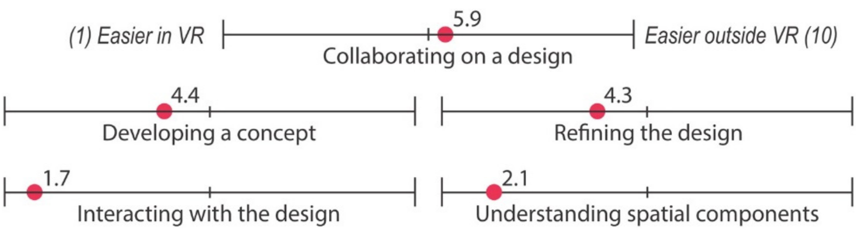

Fig. 4: Student responses on a rating scale measuring student preference by task

6 Conclusions

This study examined how students successfully integrated VR into a workflow that utilized both traditional and VR methods to analyze and develop conceptual designs on a large-scale master planning project. Overall, considering the benefits and limitations, this research shows a positive outlook for the use of VR as a tool for design creation. Using VR for analysis and concept development on a large-scale project improved students' understanding of their designs and allowed them to better express their ideas. However, limitations were observed in verbal collaboration, technology limitations, and the possibility of adverse physical effects. The benefits of the immersive design experience, combined with the rapid technological advancements and decreases in cost, suggests that VR can be successfully incorporated into the landscape architecture design process as a supplement to existing methods. This research also highlights the need for future research on the use of VR as a tool for design creation and how VR impacts final design outcomes. Also, additional research will be needed to assess the effectiveness of collaboration with a team inside VR, as this technology will become more accessible in the near future.

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