IMPACTS OF IMMERSIVE VIRTUAL REALITY ON THREE-DIMENSIONAL DESIGN PROCESSES: OPPORTUNITIES AND CONSTRAINTS FOR LANDSCAPE ARCHITECTURE STUDIO PEDAGOGY

SLEIPNESS, OLE R.
Utah State University - ole.sleipness@usu.edu

GEORGE, BENJAMIN H.
Utah State University - Benjamin.george@usu.edu

1 ABSTRACT

This study evaluates the potential of immersive virtual reality (VR) to impact the design process of students engaged in a landscape architecture studio design setting. Immersive VR has potential to increase students' understanding of three-dimensional spatial impacts while making design decisions, potentially improving their design capabilities but poses challenges as well, particularly for collaboration and larger-scale sites with significant topographic features. Following observation students' engagement with a VR-based project, a survey, questionnaire, and focus group discussion solicited feedback from study participants. Participants self-reported improved awareness of the three-dimensional spatial relationships within their designs, and an improved ability to visualize these relationships. Results suggest VR may enhance development of initial design concepts and understanding of spatial relationships. Students also reported that VR's immersive interactions significantly altered their approach to designing—and hindered their ability to communicate with others within collaborative design activities. As with many emerging technologies, VR will potentially impact landscape architecture's creative processes and will change how the discipline is taught and practiced professionally. These potential transformative impacts will provide fodder for discussion as our discipline strives to maximize VR's benefits while mitigating its challenges.

1.1 Keywords

Virtual Reality, Design Pedagogy, Technology

2 INTRODUCTION

2.1 Study Purpose

In this study we assess the use of immersive virtual reality (VR) as a mechanism for designing landscapes in a university landscape architecture design studio. VR has the potential to be a powerful tool to help facilitate design because it provides the designer with the ability to design a landscape in three-dimensions and digitally in-situ. This ability to design immersively may be particularly valuable to novice and less-experienced designers—many of whom find it cumbersome to visualize a design in 3-dimensions while laying out the design in 2-dimension, either on paper or a computer screen. The advent of easily accessible 3-dimensional modeling software, such as Sketch Up, has provided designers with a more effective method for visualizing their designs in the 3-dimensions, but these programs still fail to provide a truly immersive site experience as the designer is designing the project from without the site and is constrained by the software interface. By utilizing immersive VR as a design mechanism, we theorize students may improve their design abilities and outcomes by situating them within their design site and increasing spatial awareness of their design decisions. However—within its current state of development—we also found VR impeded communication that landscape architects are accustomed to using during collaborative design activities, and its application to larger sites with significant topographical character is severely limited. Consequently, the discipline of landscape architecture must grapple with the potential ramifications of VR on the scale and collaborative character of design—within university-based design programs and beyond.

2.2 Background

Definitions of virtual reality (VR) vary; methods of both immersive and semi-immersive visualization both are commonly described using the term. In this research, we examine the use of immersive VR, which Castronovo, Nikolic, Liu & Messner (2013) describe as a computer environment that crafts a “convincing illusion and sensation of being inside an artificial world.” This illusion of reality can potentially make VR a powerful design tool, especially if designers can grapple with the complex physical realities of a site while simultaneously designing on the site as they are completely embedded in the virtual world, with the ability to interact visually, audibly, an physically (Slater and Usoh, 1993). Ability to meaningfully interact with the digital elements within virtual reality is a crucial element that provides the viewer with a rich and immersive experience (Grau, 2003). VR headsets, such as the HTC Vive and Oculus Rift, are an example of immersive virtual reality. By comparison, in semi-immersive VR the viewer is only partially enclosed by the virtual world in any number of sensory inputs (e.g. visual, audible, physical). Popular implementations of semi-immersive VR include CAVE VR systems or large wrap-around format screens on which imagery is projected. While semi-immersive VR has been proven as a powerful visualization tool, the sense of presence within the virtual world is significantly less compared to immersive VR (Hoffman, Richards, Coda, Richards, & Sharar, 2003; Stevens & Kincaid, 2015).

As an emerging technology, VR has begun to establish a track record in design education, with many examples of semi-immersive VR as an effective mechanism for visualizing landscapes. However, these uses of VR are passive and do not utilize VR’s spatial capabilities to facilitate design making in real-time. Portman, Natapov, and Fisher-Gewirtzman (2015) conducted a review of research on VR in the design fields and found that, especially in landscape architecture, VR has been primarily used as a visualization tool. Similarly, Freitas and Ruschel (2013), in evaluating the use of VR in architectural design, found that nearly all of the published research assessed VR as an evaluative visualization tool in the design process.

Bullinger, Bauer, Wenzel, and Blach (2010) demonstrated that semi-immersive VR could positively impact the design process by evaluating a design through VR at different stages of design development. Similarly, Castronovo, et al. (2013) concluded that both immersive and semi-immersive VR are effective mechanisms for critiquing and evaluating designs due to viewer’s perceptions of immersion within the design. VR can also be utilized to facilitate collaboration and other social interactions. Gu, Kim, and Maher (2011) utilized semi-immersive VR to facilitate collaboration among individuals, and Dunston, Arns, and McGlothlin (2011) had users collaboratively interact with virtual design elements in an immersive setting.

VR’s ability to increase spatial-related factors has motivated the design disciplines to apply the technology. Castronovo et al. (2013) note that VR can present spatial information more accurately and in more quantity than conventional means, leading to improved spatial awareness among viewers. George

(2016) successfully utilized VR to conduct a remote site analysis and found students were able to accurately interpret spatial site qualities. However, Gill and Lange (2015) and Lange (2011) caution that VR separates users from the physical site and its sensory experiences, noting that individual users will apply different spatial and value perceptions to the site regardless of the level of detail used in the visualization. Moreover, designers within VR cannot smell the site's aromas, feel its wind and weather, or experience all the serendipitous facets of the site such as the onset of changing weather, encounters with wildlife or strangers, or hear all of its ambient sounds. Portman, et al. (2015) noted that VR improves spatial conception when used to visualize a design. Bullinger, et al. (2010) have raised concerns that semi-immersive VR does not provide sufficient spatial immersion to assess design ideas. However, Rahimian and Ibrahmi's (2011) study, which utilized non-immersive VR, found that VR encouraged students to more meaningfully consider the three-dimensional nature of their design work.

Except in the case of Rahimian and Ibrahmi (2011), the literature describes VR's design application as interpretive—whether visualizing a site or design, the viewer's experience is fundamentally defined as consuming rather than generating spatial information. Very little research has been conducted VR's application in generating spatial information—how it can facilitate the actions of designing. While Chamberlain (2015) explored the use of VR to generate hypothetical cityscape scenarios but the scale and tools used would preclude the design of site-scale landscapes. The lack of exploration into design creation with VR may largely be attributed to technology. Prior to the release of Oculus' VR headset in 2015, VR headsets were cumbersome and expensive; VR's ability to input information from hand gestures became affordable when HTC released the Vive VR headset in 2016. Based on the ability of immersive-VR to provide immersion and improved spatial awareness, the possibility to utilize VR as a design input tool in addition to its visualization capabilities, provides abundant opportunities for research.

3 METHODS

This study describes VR's impacts, opportunities, and constraints as a design tool. The study's sample (n=29) was drawn from a junior-level recreation design studio course in an accredited landscape architecture program in the U.S. A total of 24 undergraduate students were enrolled in the course, comprised equally of males and females. An additional three female and two male graduate level MLA students also participated in the studio. First, students were asked to self-assess their proficiency and use of both digital and hand graphic representation techniques. Next, the study utilized a qualitative singular case study approach, conducted over two scheduled studio sessions totaling six hours, to evaluate students' feedback on VR programs (Yin, 2008). Initially, students were divided into groups of five groups, each comprised of five or six students. Teams were provided a design problem statement. The problem statement—based on the concept of Park(ing) Day—instructed students to design a micro-scale park in VR that would replace a parking stall and include several common landscape features such as seating, vegetation, and site fixtures. Within their assigned teams, students used an HTC Vive, an immersive-VR headset that features handheld "wands" that track the user's physical movements and enable the user to input data and draw through gestures. The students used SculptrVR, a 3d modeling program in which to build their designs using a similar gestural process.

In their teams, each team of students occupied a designated studio space and took turns collaboratively designing a micro park. While one student worked in VR, the remaining students in the team observed what was created in VR by watching their VR colleague gesture within their designated physical space and the progress of their design a large monitor. The observing students provided feedback and suggestions to their colleague in VR. Despite receiving this feedback, the design exercise was largely individual in nature, due to the agency provided by the VR controls. During this activity, the researchers observed and documented the process through notes, photographs, and video. This observational data provided one set of data for analyzing the way in which they interacted with the medium and its impacts on their design process. At the conclusion of the project, the researchers held a focus group session with the students to discuss their experience with VR and allow the students to vocalize their observations on the affordances and constraints of the medium.

4 FINDINGS

According to students' self evaluation, designing in VR significantly impacted student's approach to design, particularly in their awareness of spatial considerations and improved freedom of expression. Students responded positively to VR's ability to enable them to immediately understand the 3-dimensional nature of their design and to consider their design decisions' spatial impacts. Consequently students reported they were much more cognizant of their design decisions' spatial impacts, than if they had designed the same project on paper or at a computer screen. Students also reported VR provided them with greater freedom of expression during the design, especially compared to designing on a computer screen. In particular, students felt the HTC Vive' spatial tracking combined the benefits of both 3-D modeling and traditional drawing. Students were able to create 3-D models using SculptrVR by applying traditional drawing gestures, which they reported as a symbiotic creative relationship between digital and hand design production. Additionally, students were able to easily interact and move within their design, providing several serendipitous moments of discovery, during which they recognized ways to improve upon their design or add details.

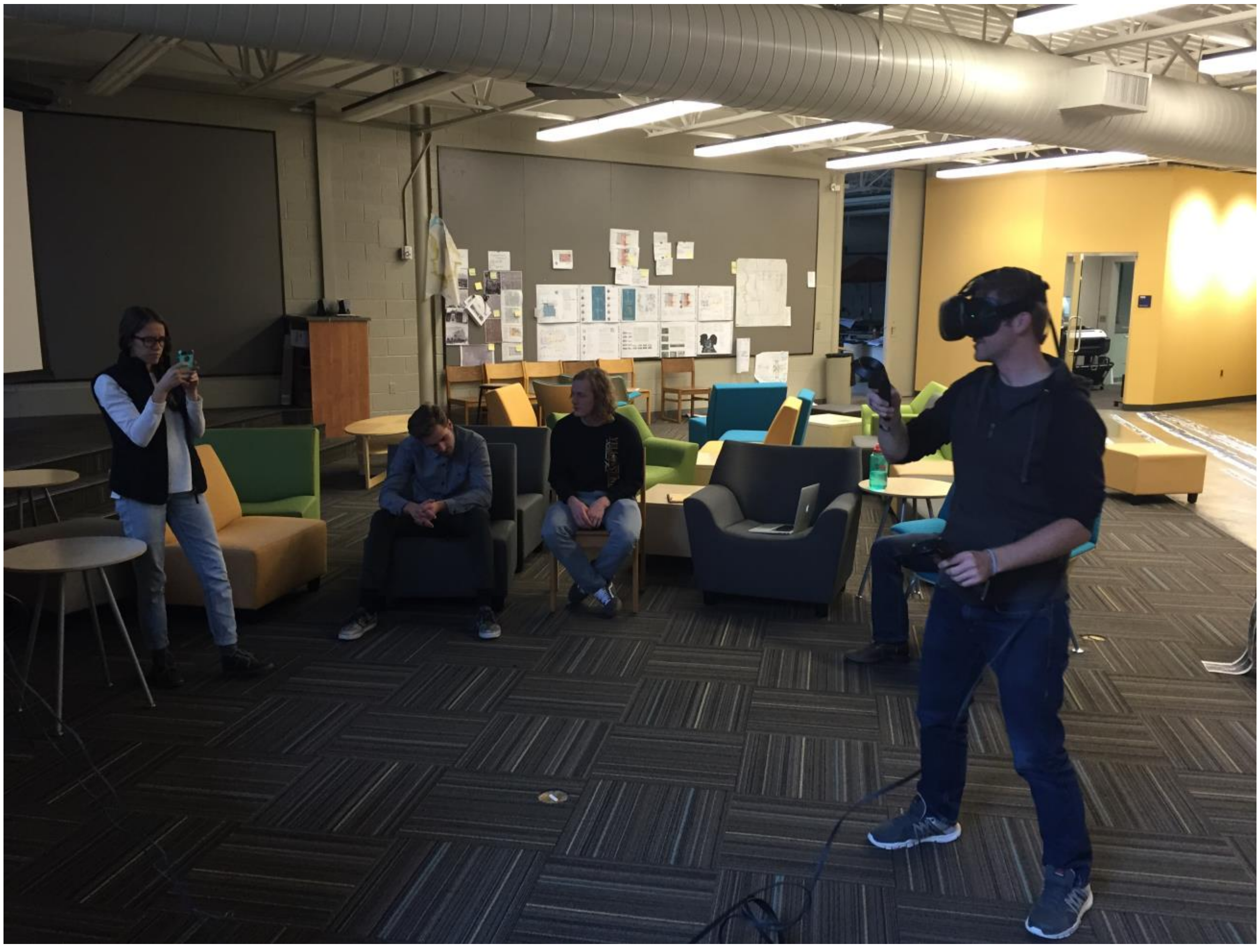

Figure 1: A Student designs in VR while his colleagues provide verbal feedback.

However, the VR interface also presented challenges to design creativity and collaboration, and students reported frustration with some elements of designing in VR. While the learning curve for the VR headset was very short—students frequently commented on how natural it was to use—respondents felt SculptrVR's software interface was not as intuitive or flexible as they would have preferred. Consequently, several students used only a few tools or colors in their models, because they found the process of adjusting the settings confusing or distracting. Additionally, because SculptrVR uses scalable cubes as the basic unit for modeling, students reported the modular cube geometry was distracting when attempting to create curved objects. Finally, although the exercise was designed as a collaborative activity, students found it awkward to collaborate with their colleague in VR. Students observing from outside of the VR could only provide vocal feedback to their colleague who was working within VR, which was both frustrating to both those within and outside of VR. Additionally, the images displayed on the monitor did not accurately convey the design that was being created and experienced by the student in VR, leading some observing students to make comments that reflected differences in perception between those in VR and those outside VR. Consequently, though the exercise was first conceived as a collaborative design activity, instead it became primarily an individual design activity, albeit with rigorous peer observation and feedback.

Overwhelmingly, students responded favorably to using VR, reporting that VR helped facilitate their design work by improving their spatial awareness of their designs in real time. Their responses confirm VR's spatial benefits—realized for decades as visualization tools—are equally applicable to designing within VR. They suggest VR has potential to greatly impact the pedagogy and practice of landscape architecture as the technology matures. Improved spatial awareness during the design process and its impact on development of their designs are among the technology's positive impacts reported by the students. For instance, one student commented how VR helped her "better understand how important scale is, even in simple design tasks." Another commented that it "was easier to get a feel for dimensions and the relationships" in the design. Another student described how he was "more aware of the space elements take and that every step of the design process affects actual space" impacted his design process. These comments demonstrate the immediate and beneficial impacts that VR can have on students learning to design. Many of the students felt that their experience with VR would directly benefit their design work outside of VR because they were now more aware of the need to think 3-dimensionally.

Despite students' positive feedback, there are drawbacks to the use of VR to design. The drawback most immediately apparent to the students revolved around the cube-based geometry that SculptrVR uses, which hampers creation of curvilinear, naturalistic, or organic forms—or at best adds a geometric texture to organic forms. Consequently, resulting designs had a rough quality several students found frustrating. Students referred to their designs as "blocky" and found the visual aesthetic of the program to be distracting. A lack of high degree of fidelity limits students' abilities to create detailed or refined design elements and forced them to instead focus on general concept development within their design. From a pedagogical perspective, this limitation can be interpreted either negatively or positively. Those attempting to use SculptrVR to develop refined and detailed design decisions may find the technology ill-suited for their purposes. However, just as design faculty often limit the palette of graphic tools available to their students to limit precision and instead produce broad, conceptual, and bold gestural designs, SculptrVR may be viewed as akin to a thick marker or soft charcoal pencil. Realistic awareness of the graphic limitations of VR will enable users to determine appropriate applications for employing the technology.

5 DISCUSSION

In its current level of development, SculptrVR's ability to facilitate collaborative design was more limited than anticipated. Students found collaborating and discussing within VR to be difficult. Occasionally, students within the VR found it difficult to implement suggestions from viewers, because they had to rely on listening to verbal suggestions and subsequently try to implement those suggestions in a visual manner to the best of their understanding. Similarly, some viewers found clearly vocalizing their feedback challenging. This led the students to recognize how heavily we rely on visual language to communicate design ideas. This was complicated by the fact that the experience of the design from within VR is markedly different to the 2-D image displayed for the viewers on the monitor.

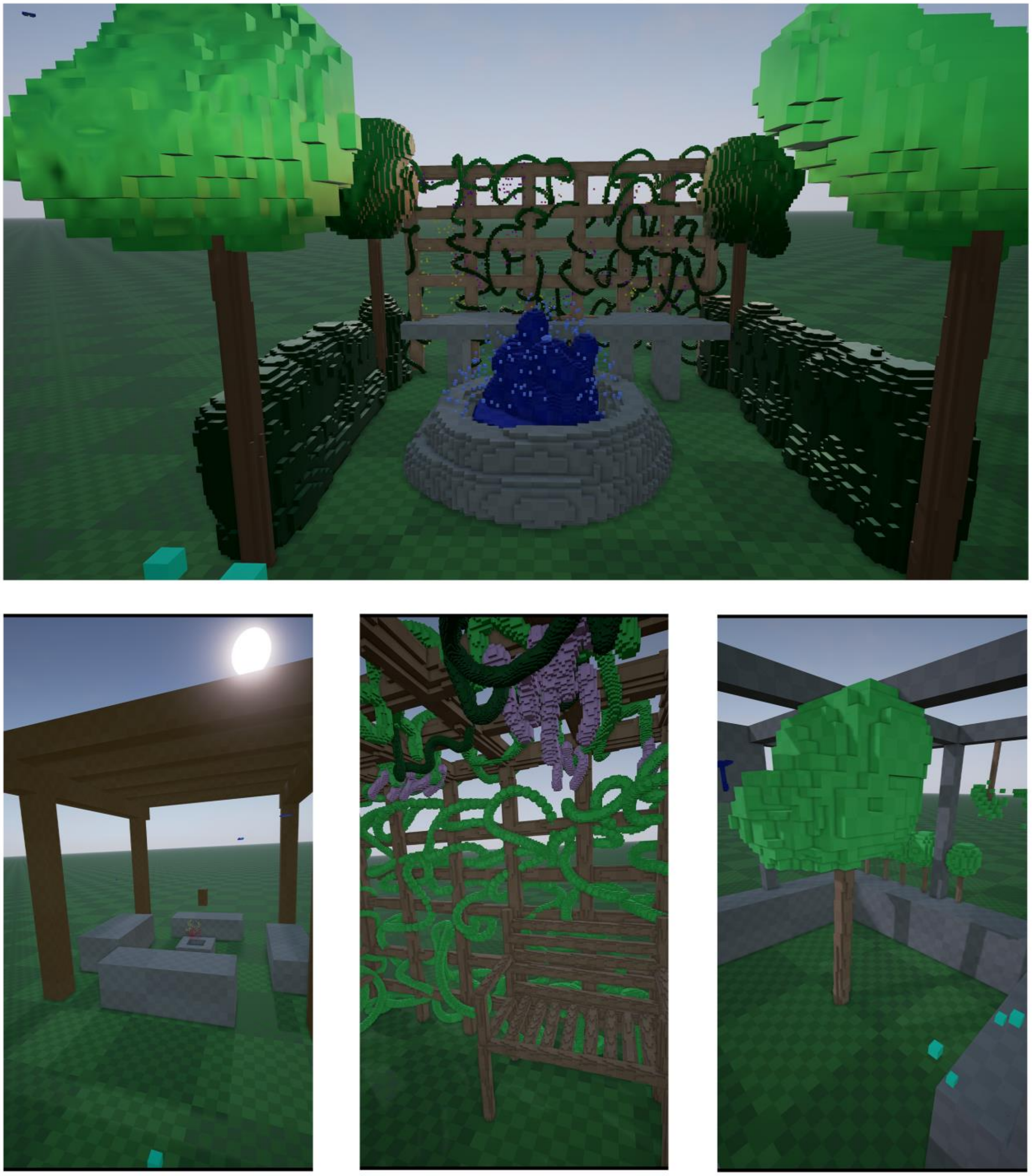

Figure 2: Example images of student design work from SculptrVR.

This led viewers to make suggestions that they may not have vocalized, had they been in the VR and immersed in the design. Likewise, students designing found receiving comments from those viewing their designs on the monitor confusing or not applicable, because the commenting observer had a false impression of the site based on their distorted view from outside VR. The differences in visual perceptions raises a concern with immersive-VR. In providing a fully immersed experience for the user, VR simultaneously cuts them off from the outside world. In this manner, their horizon of observation is severely limited, making it more difficult for them to actively collaborate with others (Hutchins, 1995). Furthermore, this demonstrates the difference in collaboration effectiveness between semi-immersive and immersive-VR, as previous studies had found semi-immersive-VR were very conducive for collaboration (Gu, et al., 2011; Castronovo, et al. 2013). SculptrVR also supports multi-user design, in which multiple VR users can work on a design simultaneously over the internet. Future research should explore its ability to enhance the collaborative experience and its impacts on barriers to visual communication.

Additionally, scale and terrain—factors integral to designing within large sites—are currently limited within VR. SculptrVR allows the user to create large designs, and to rescale their designs once they have been created. However, this is only possible to a certain level—and it would be difficult for a designer to switch between significantly disparate scales without degrading the VR's immersive spatial experience. For example, designs for a larger site, such as a twenty-acre park, would need to be created at a smaller scale that would not be immersive. Furthermore, the designer would be unable to "zoom in" on portions of the park to design at true scale, negating VR's immersive benefits. Consequently, in its current level of development, the immersive value of VR is limited to smaller sites. Terrain also presents challenges within VR. While difficult, terrain models can be imported into SculptrVR; however the physical environment in which the designer occupies does not replicate the virtual world being shown to the user. As a result, it is not possible to physically climb a slope in VR in the same way that a person would physically engage a site, experiencing its full sensory and tactile characteristics. Instead, the VR user would walk through the geometry of the terrain.

This study suggests that in its current development, VR is best suited for smaller sites and during broad and conceptual phases of design. Students felt that VR increased their desire and ability to explore multiple design concepts, which suggests its suitability for early in the design process. Additionally, the lack of fidelity in the created model suggests VR is best employed in development of forms and spaces but prior to designing refined levels characterized by decisions on literal materiality, Similarly to a blank canvas, several students commented that they found it difficult to initiate a design in VR, and would rather have started their design exercise by first developing a set of very rough concepts on paper which they would then develop and explore in VR. Such a workflow would assist students in better visualizing their 2-dimensional designs as they rapidly iterate and shift back and forth between 2-dimensional sketching and VR.

Finally, using VR in a studio setting was not without technical challenges. Setting up and maintaining a VR system is relatively straight forward, but requires a level of technical expertise. The HTC Vive requires sufficient open space free of obstacles; approximately 25 square feet is needed. Additionally, because the Vive utilizes synched infrared base stations to track the position of the user in space, multiple VR systems cannot simultaneously occupy the same space where the infrared from the multiple base stations might interrupt the tracking of the individual VR units. Multiple VR systems must instead be set up in separate rooms, for simultaneous operation.

The students were overwhelmingly positive in their evaluation of the immersive experience and the intuitive nature of designing in VR. Students described the experience of being in VR as feeling akin to being situated on a site, and used terms as "in the design," "in the site," and "on site" to describe their experience. Students used these terms, despite the fact they clearly were not on site, and the digital workspace displayed by SculptrVR does not resemble a physical parking lot. Rather, students described the sensation of being present within their design concept, a sensation heightened by their ability to occupy, move throughout, their design through physically walking and by creating their design through physical gestures, in a similar manner to how a designer might walk across a site and use their hands to gesture or visualize the creation and placement of elements (Figure 1). As one student described her experience designing in VR: "It felt really different to be in the space. I didn't have to think of how wide a space was. When I working with the VR, I was on site. I was going by what I felt on site." Another was even more enthusiastic in describing her experience: "I absolutely love designing in 3-D! I felt so alive and connected to my design! I could literally experience whatever I imagined!" These comments—which reflect students' excitement and positive reception of VR—also illuminate the need for caution. Within design, VR poses a double-edged sword. While its technological limitations may limit its scale and range of use, VR also possesses dazzling potential to deceive emerging designers into feeling they have experienced the reality and complexity of a site when they clearly have not. Designers' ability to deeply know the limitations of their virtual world requires deep experiences the real one. Without protracted experiences within the real landscape—and its manifold tactile qualities, sounds, smells, and physiological impacts—future generations of landscape architects will have no way of knowing what they are missing.

6 CONCLUSION

In this study we evaluated impacts of immersive VR on the design process of landscape architecture students. Based on researcher observations and participant feedback, the technology has the potential to enhance the visualization, spatial awareness and broad conceptual design abilities of landscape architecture students. However, in its current state of development, the technology also limits the scale, topographic character, and may limit the collaborative and sensory connections to that designers must cultivate to their colleagues and their physical site. Future research should explore whether VR—as the technology is refined—can be successfully applied in the design of larger-scale sites, especially those with significant topography. Additional explorations might also explore the application of immersive VR within the actual landscape of the site, to evaluate the impacts of ambient noise and other sensations on the design experience. And, additional studies might also compare the experience of designing in VR to similar analog three-dimensional design processes including physical construction of models using light-weight and moveable objects in true-to-life spaces. Comparative evaluation of designing three-dimensional spaces using VR vs. analog construction of mock-ups will provide additional clarity on their respective constraints, benefits, and impacts on collaborative design.

Throughout history, technological advances have transformed the habits and practices of cultures. Some may find VR's current limitations outweigh its potential benefits. However, as VR continues to develop and its design capabilities evolve, landscape architecture should contemplate its potential impacts on our discipline's habits, practices, and culture. Landscape architecture's long-established culture of creativity and collaboration, enculturated in university design program studios, professional offices, and outreach activities will likely be impacted by VR, just as it has been by other once-emerging technologies. While some may presently regard VR as simply the latest novel design entertainment, its potential future indispensability as a design tool will have wide-ranging impacts on how we create, teach, and practice.

7 REFERENCES

Bullinger, H. J., Bauer, W., Wenzel, G., & Blach, R. (2010). Towards user centred design (UCD) in architecture based on immersive virtual environments. *Computers in Industry*, *61*(4), 372-379.

Castronovo, F., Nikolic, D., Liu, Y., & Messner, J. (2013). An evaluation of immersive virtual reality systems for design reviews. In *13th International Conference on Construction Applications of Virtual Reality, London* (pp. 22-29).

Chamberlain, B. (2015). Crash course or course crash: Gaming, VR, and a pedagogical approach. *Proceedigns of the 2015 Digital Landscape Architecture Conference*, 354-361.

Dunston, P. S., Arns, L. L., Mcglothlin, J. D., Lasker, G. C., & Kushner, A. G. (2011). An immersive virtual reality mock-up for design review of hospital patient rooms. In *Collaborative design in virtual environments* (pp. 167-176). Springer Netherlands.

Freitas, M. R., & Ruschel, R. C. (2013). What is happening to virtual and augmented reality applied to architecture?. In *Conference on Computer-Aided Architectural Design Research in Asia (CAADRIA 2013)* (Vol. 1, p. 407-416).

George, B. H. (2016). Distributed site analysis utilizing drones and 360-degree video. *Digital Landscape Architecture*, 1, 92-96.

Gill, L., & Lange, E. (2015). Getting virtual 3D landscapes out of the lab. *Computers, Environment and Urban Systems*, *54*, 356-362.

Grau, O. (2003). *Virtual Art: from illusion to immersion*. MIT press.

Gu, N., Kim, M. J., & Maher, M. L. (2011). Technological advancements in synchronous collaboration: The effect of 3D virtual worlds and tangible user interfaces on architectural design. *Automation in Construction*, *20*(3), 270-278.

Hoffman, H. G., Richards, T., Coda, B., Richards, A., & Sharar, S. R. (2003). The illusion of presence in immersive virtual reality during an fMRI brain scan. *CyberPsychology & Behavior*, *6*(2), 127-131.

Hutchins, E. (1995). *Cognition in the Wild*. MIT press.

Lange, E. (2011). 99 volumes later: We can visualise. Now what?. *Landscape and Urban Planning*, *100*(4), 403-406.

Portman, M. E., Natapov, A., & Fisher-Gewirtzman, D. (2015). To go where no man has gone before: Virtual reality in architecture, landscape architecture and environmental planning. *Computers, Environment and Urban Systems*, *54*, 376-384.

Rahimian, F. P., & Ibrahim, R. (2011). Impacts of VR 3D sketching on novice designers' spatial cognition in collaborative conceptual architectural design. *Design Studies*, *32*(3), 255-291.

Slater, M., & Usoh, M. (1993). Representations systems, perceptual position, and presence in immersive virtual environments. *Presence: Teleoperators & Virtual Environments*, *2*(3), 221-233.

Stevens, J. A., & Kincaid, J. P. (2015). The relationship between presence and performance in virtual simulation training. *Open Journal of Modelling and Simulation*, *3*(02), 41.

Yin, R. K. (2013). *Case study research: Design and methods*. Sage publications.

Hoffman, H. G., Richards, T., Coda, B., Richards, A., & Sharar, S. R. (2003). The illusion of presence in immersive virtual reality during an fMRI brain scan. *CyberPsychology & Behavior*, *6*(2), 127-131.

Stevens, J. A., & Kincaid, J. P. (2015). The relationship between presence and performance in virtual simulation training. *Open Journal of Modelling and Simulation*, *3*(02), 41.