Impact of the digital design process in an architectural engineering technology program: Integration of advanced digital tools (work in progress)

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Abstract

An architectural design course demands a wide range of creative design approaches. To strengthen design concepts, students are encouraged to employ diverse digital tools during their ideation process. Traditional methods of representation include sketching, drafting, and modeling that explain the spatial organization and relationships. Although these methods provide an understanding of the design ideas, they cannot provide an immersive experience. Digital tools and platforms such as Building Information Modeling (BIM), Virtual Reality (VR), Augmented Reality (AR), Mixed Reality (MR), metaverse, and rapid prototyping help students gain an empirical understanding of space. The recent advancement of VR gear, software, and applications lowered the threshold for designers and readily provides pedagogical options for exploring immersive experiences. The integration of digital tools helps designers quickly manifest a three-dimensional environment and explore various compositional and spatial options. Through this process, the digital tool is transcended beyond a mere visualization tool and becomes a methodology to achieve better design. For the past several years, the author has had the opportunity to integrate various digital tools in architectural design courses to examine the implications of the digital design process. Participating students were introduced to architectural theory and experimented with various design strategies using digital tools. They employed BIM for modeling their designs and translated the designs to VR files for presentation and review sessions. The student viewers were able to use affordable VR gear Google Cardboard to evaluate and conducted peer reviews of the student projects. Furthermore, in the current course, the author is experimenting with VR gear and its applications as an experimental design tool that provides interactive 3-dimensional modeling capability in the VR environment. This work-in-progress paper will analyze the use of digital tools in the architectural design process and evaluate the validity of the tools as pedagogical content in an architectural design course.

Introduction

The rise of remote learning and working during the COVID-19 pandemic, suggests that various types of immersive software can be adapted to the architectural field. [1] The platforms that foster virtual collaboration are defined below.

- Virtual Reality (VR): This technology refers to a digitally generated simulation of a 3D environment that can provide the user with an immersive experience with special electronic equipment as shown in Figure 1.1. Typically, the VR headset covers the user's eyes and employs handheld controllers to interact with the virtual content, shown in figure 1.2. VR has a wide range of applications and in architecture and design, VR can be used for visualizing designs, presenting to clients, and for creating virtual walkthroughs of buildings before they are constructed. [2]

Figure 1.1 Image Courtesy Meta

Figure 1.2

- Augmented Reality (AR): This technology provides the means to overlays digital information on a real-world display. AR involves using an electronic device with a camera to display digital information superimposed on the real-world view seen through the device's screen. AR enhances the physical world by providing additional information and it can be used to interact with virtual objects. In architecture and design, AR can be used for visualizing designs and for interactive presentations that allow the audience to explore designs. [2]

- Mixed Reality (MR): This technology blends virtual and real-world elements to create an interactive experience. It combines the benefits of VR and AR to create a mixture of digital and physical environments. In MR, digital content is integrated into the real world, permitting users to interact with virtual objects. Applications of mixed reality span various fields and in design, mixed reality can be used for prototyping, visualizing, and collaboration. [2]

- Metaverse: The metaverse refers to a digitally immersive environment, typically a shared space generated by multiple digital mediums that simulate the physical world. The platform is a collective and connected space where the users can interact and collaborate with virtual elements facilitated by VR equipment. [2]

VR, AR, MR in architecture

The experiential qualities of VR, AR, and MR technologies can be integrated with the architectural design process. There are two aspects of the immersive process that can be implemented in the architectural field and architectural education. One aspect is the virtual representation of the design, giving users the experience of the spatial design. The other aspect is the iterative design process with the technology that can provide immersive and generative design tools to explore design iterations.

- *Immersive experience*

  VR technology is commonly used in the architecture industry to create immersive and interactive experiences for clients, letting them move through a proposed space before the completion of the building. This technology can assist designers and clients by providing

enhanced visualization and understanding of the space, allowing them to make more informed decisions. VR can also be used for visualization enabling architects to create realistic renderings and animations for the design presentation. Lastly, VR can be used in construction, warranting the builders to plan and visualize the construction process before construction work begins and aiding builders in identifying potential issues and making necessary adjustments to the design prior to construction. In architectural education, students can use VR technology to present their work in an immersive and interactive way. The VR can also be used on a virtual site visit to allow students to experience real-world projects. This option assists the students to experience the site if they cannot visit in person.

- *Immersive design*

  The iterative design process with VR, AR, and MR can provide immersive design tools for users to explore design options. The technology can be used to create virtual models and prototypes of architectural designs, letting students explore and experiment with different design options in an immersive and interactive way. The main platform and immersive environment can be set in the metaverse which allows students to explore designs and make modifications in real-time. Students are able to experience the space in a way that would not be possible with traditional two-dimensional drawings or physical mockups. VR also provides a platform for collaboration and communication between instructors and student groups, regardless of location.

  VR technology supports cross-program workflow to connect with other software for simulating diverse design concepts and evaluating the generated models. The workflow can begin with the digital modeling software that can generate design concepts and transfer the model to virtual reality environments where the users can manipulate or refine the designed components. Alternatively, the user can generate design concepts in virtual environments using VR technology and transfer the model to digital modeling software such as Autodesk Revit, McNeel's Rhinoceros, and SketchUp. Both workflows can enhance the design as it provides a generative and iterative process in the immersive environment. The industry has much better digital modeling proficiency in 3D modeling software, but VR modeling skills can be taught with a readily available training program.

  Once the model is finalized, students have the option to translate the model into a rapid prototype with a 3D printer which provides a scaled physical model. This workflow can be an alternative option for the traditional physical model-making process allowing design exploration with efficiency.

Background

The architectural engineering program at Farmingdale State College, State University of New York has a strong focus on hands-on and experiential learning through a variety of curricula. Students learn about architectural design, regulations, sustainability practices, materials, and methods. They also gain creative design processes through diverse courses that are non-technical. The Architectural design courses span five semesters and emphasize the design of buildings, including their form, function, history, and theory of architecture. This design course sequence starts with the Architectural Design I class which includes many fundamental design exercises such as physical and digital modeling projects. As the course stresses the importance

of form and spatial design, the students are asked to put together physical models that have the benefit of representing the design concept in 3-dimensional form with diverse materials. [3] An additional purpose of the physical model is to analyze the design to gain an understanding of the spatial relationship, scale, and to visualize the overall form of the structure. Since the model can be made from various materials, the physical model helps students gain hands-on learning experience by selecting materials, preparing the design elements, developing problem-solving skills, and assembling the components. Ultimately, the students present their work in a series of presentation formats where they learn communication, collaboration, and leadership.

The alternative or supplementary option for this pedagogical process in Architectural Design I course is to utilize digital modeling tools, such as AutoCAD, Revit, Rhino, SketchUp, or 3D Studio Max, which are the industry's most common software. The digital tools provide an efficient and convenient modeling process in that students can visualize and explore their design options quickly and generatively with multiple iterations. [4] Additionally, digital modeling has the ability to represent complex forms that cannot be realized in physical models. The process can also encourage students to explore dynamic and fluid shapes that are rooted in the parametric modeling process with computational and iterative design logic. This not only helps the designers to visualize but to realize the forms through rapid prototyping with 3-dimensional (3D) printers. [5]

While physical and digital modeling has various benefits for exploring design iterations, they do not provide an experiential aspect of architecture. The full-scale physical mockup or animated rendering can offer the experience but it does not give an interactive understanding of the complete spatial design. Adaptation of VR, AR, and MR in design courses can suggest endless experiential possibilities with an immersive, iterative, and interactive design process. [6]

Implementation and methodology in design courses

VR, AR, and MR technology can be integrated into architectural design courses in diverse ways. The author had an opportunity to teach an Architectural Design I class which focuses on the fundamental architectural design process as well as developing presentations using physical and digital models. The class has five design projects during the semester, a mixture of creating conceptual models using physical materials and using digital modeling software to develop design interventions. Both methods are equally important as the learning outcomes call for hands-on learning experiences as well as training on industry-standard design tools.

The first three weekly projects focus on the hands-on learning experience through the physical model-making process. Project 1 places an emphasis on the creation of form with primitive geometries. The students are asked to create a physical model using a sugar cube as a building block to express basic shapes such as circles, triangles, and rectangles as shown in Figure 2.1. In the second project, students use wooden dowels to create space with primitive geometry as shown in Figure 2.2. The last weekly project utilizes matt board to represent planes to define small, medium, and large interacting spaces as seen in Figure 2.3. All the students create a presentation with their physical models while the class conducts peer review through a Google form survey. [7] The grading category represents the interaction of the form and clear representation of the forms. During this process, the author randomly divided the class in half, with one group of students being required to build a digital model prior to putting together a physical model as shown in Figure 2.4 while the other group was required to develop a physical model only. Due to the small sample size, the findings suggest insignificant differences and are

inconclusive. The author continues to collect data for more significant findings in the upcoming semesters.

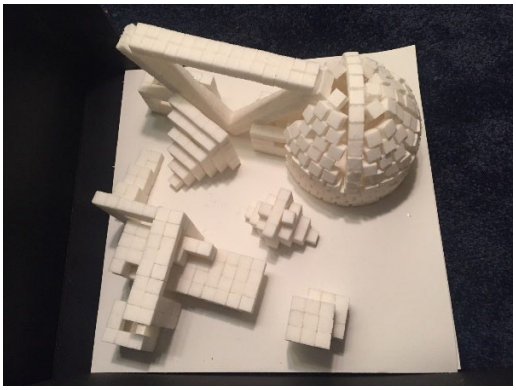


Figure 2.1

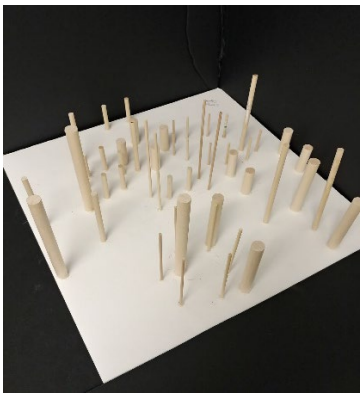


Figure 2.2

Figure 2.3

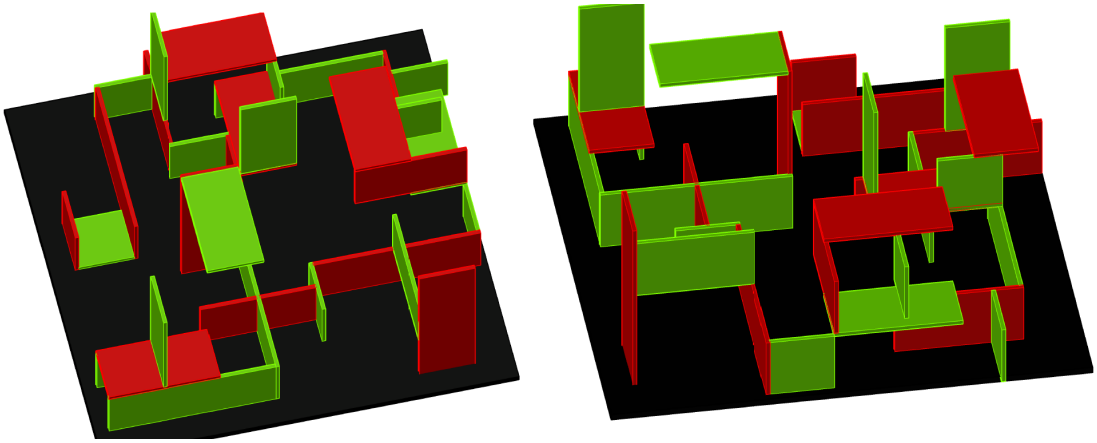


Figure 2.4

The remainder of the semester is dedicated to developing architectural scale projects using digital models. In this process, the majority of the students use AutoCAD and Revit. The VR is used as a presentation tool as the students can render VR files from Revit and generate interactive and immersive views of their projects. The student peers can view the project through their phone screen by scanning the QR code provided by Revit as shown in Figure 2.5. This image then can be viewed through a VR headset such as Google Cardboard which is an affordable VR gear that has a glass lens to view the phone screen, shown in Figures 2.6 & 2.7. This presentation format helped the student peers to have an immersive experience of the presenter's 3D digital model. The students also utilized VR technology during the design phase. The efficient output from Revit rendering to VR file allowed the students to quickly evaluate and refined their design interventions. One of the weaknesses during this process is the fixed view with the camera position which does not permit the users to "walk" around the design. Also, the VR technology is limited to viewing only and it does not offer modeling capabilities directly in Revit. The survey was conducted, and the result suggests that most of the students see VR as a helpful tool for understanding spatial design and helping them to achieve better 3D design.

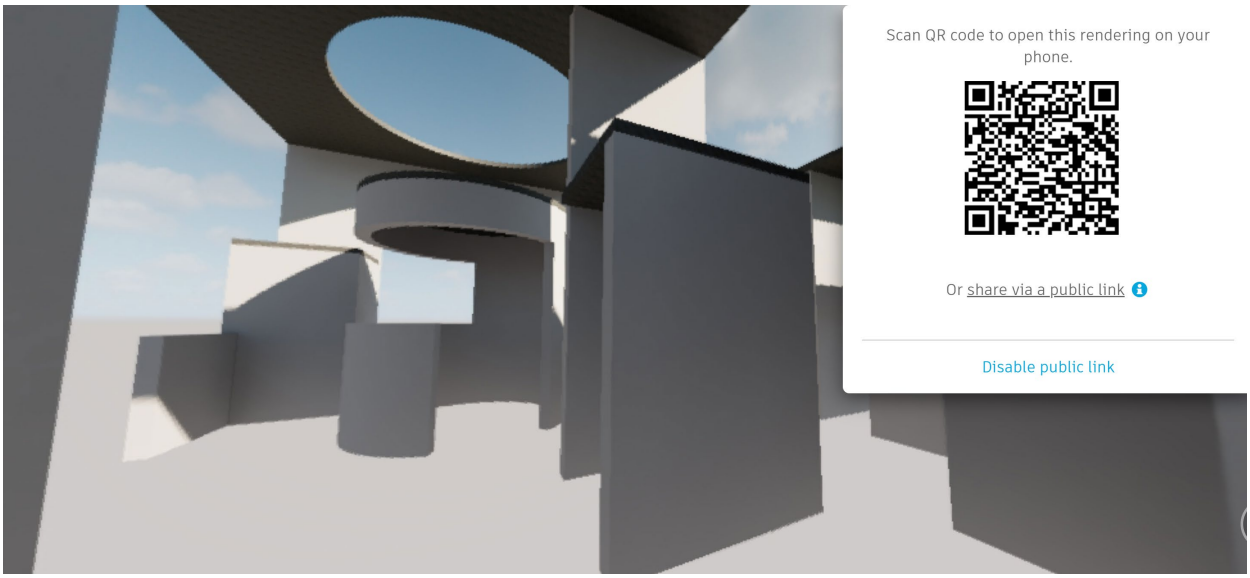


Figure 2.5


Figure 2.6

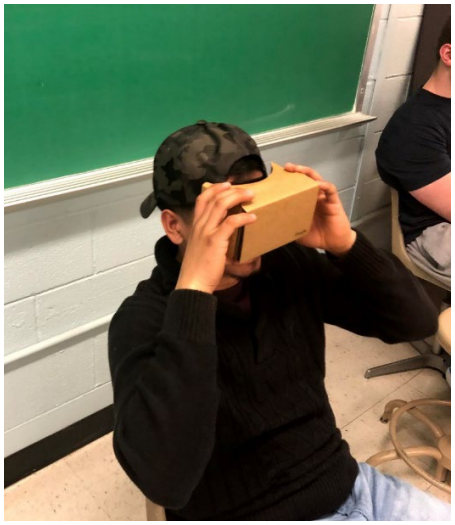


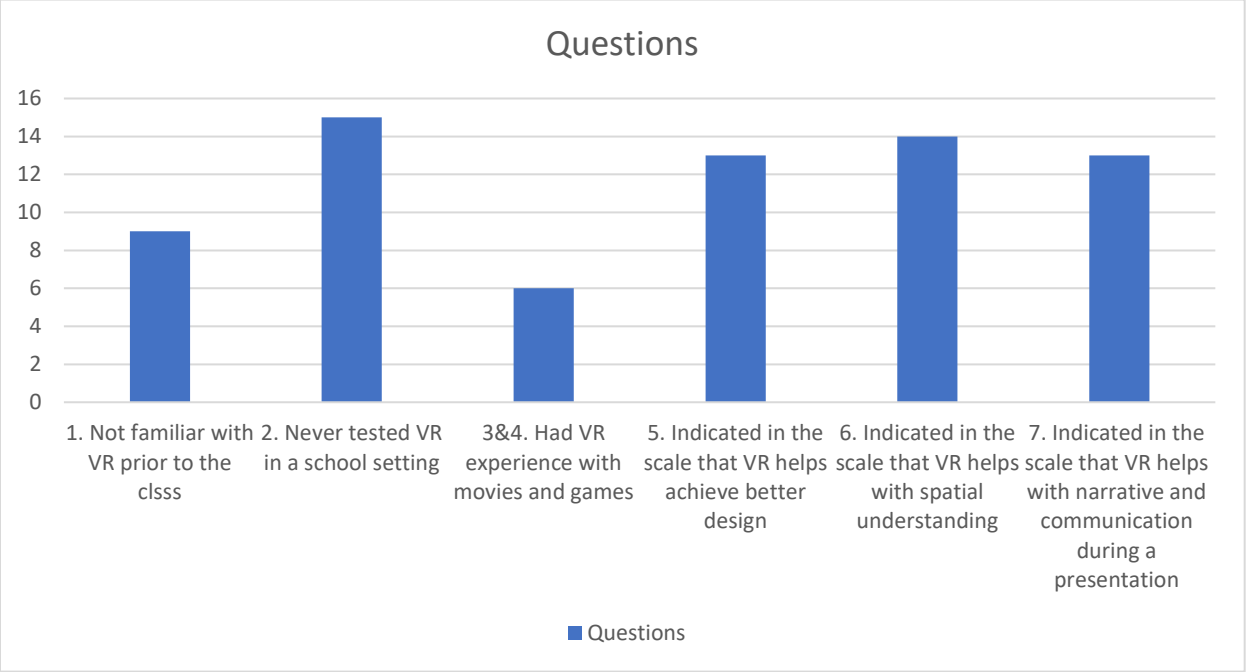
Figure 2.7

Survey

Questions

1. How familiar were you with the concept of virtual reality (VR) prior to this class?
2. Have you ever tested VR or tried it in school prior to this class?
3. Have you ever tested VR or tried it in other settings?
4. If you have tried VR in other settings, please describe
5. Did using VR help achieve better design?
6. Did using VR help with spatial understanding?
7. Did using VR help with narrative and communication during a presentation?

Survey Results (N=15)



Background research, logistics, and the next step

Options for the iterative design process in an architectural design course

The next experimentation with VR technology in the architectural design course is to use a VR headset, such as Meta Quest which has an application that allows the users to build space and geometric forms. The application Arkio is a collaborative spatial design tool that has the following functions which can be adopted in place of the traditional design process.

- Solid modeling: live modeling process with VR gear that allows users to perform extrusion, Boolean, and create parametric volume as shown in figure 3.1. The intuitive editing capabilities include copying, moving, pasting, snapping, skewing, and carving.

Figure 3.1 Image courtesy Arkio

- Cross-program workflow: Arkio provides seamless importing and exporting of 3d models from Revit, Rhino, and SketchUp. These tools allow the students to build models using the software with more proficiency and to import in Arkio to refine based on the immersive evaluation.
- Cross-device workflow and collaboration: Arkio offers collaboration between various devices. The model can be viewed and edited on tablets, phones, and PC. Student collaboration becomes more convenient and efficient between diverse devices as shown in Figure 3.2.

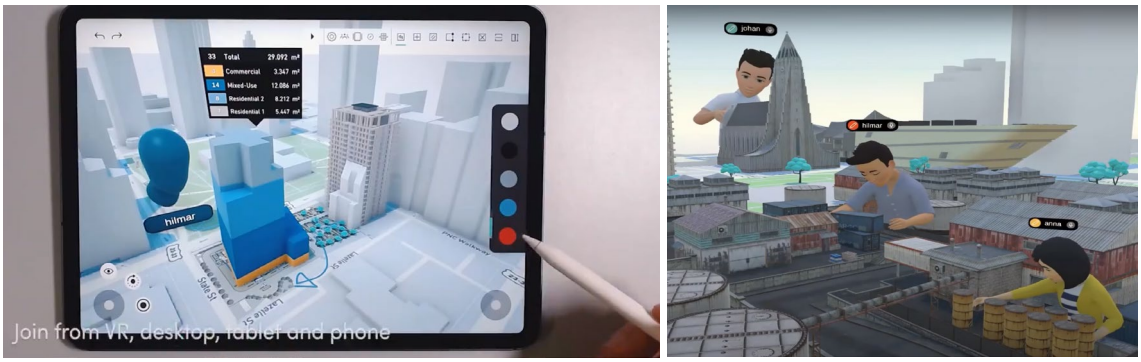


Figure 3.2 Image courtesy Arkio

- Import LiDar scans: This feature allows the existing space to be scanned with LiDar technology and imported to Arkio for modeling and modification, shown in Figure 3.3.

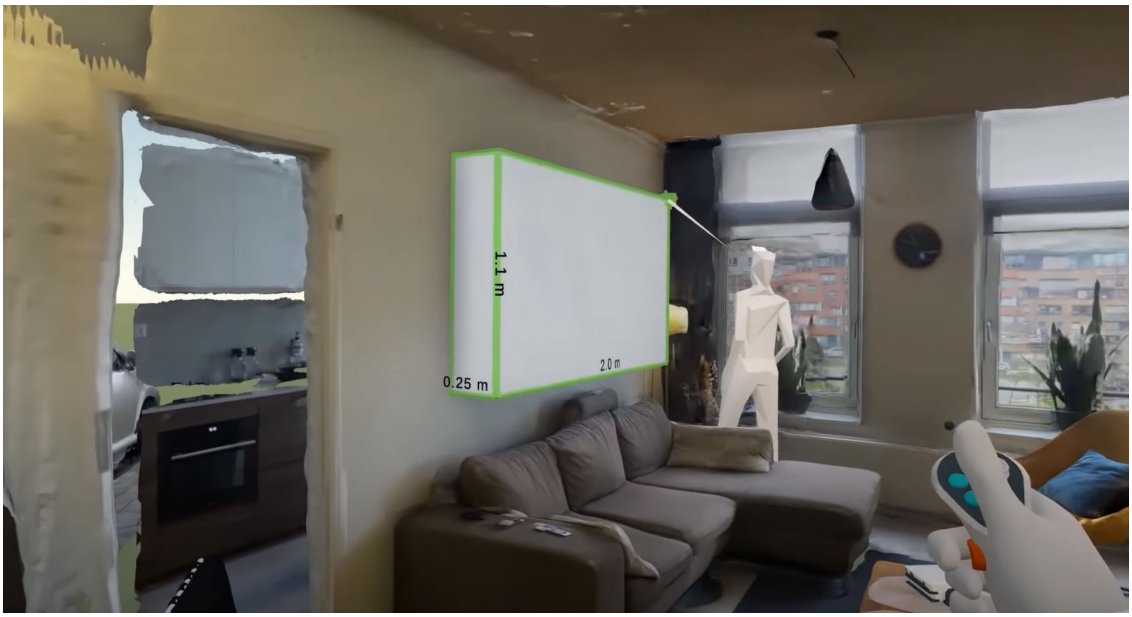


Figure 3.3 Image courtesy Arkio

Current experimentation and investigation

The author has an opportunity with the current architectural design course to use a gaming application in Meta Quest, Minecraft as an iterative and experimental design tool with 3d rapid prototyping. Many students are familiar with the game and comfortable using the modeling interface. The Minecraft environment is highly spatial and provides a sense of scale, optimal for architectural projects. The game items can be used as a building block to create architectural forms and develop a design concept. Also, this metaverse environment can be accessed by all the students with an affordable Minecraft account. This easy access fosters student VR collaboration and effective remote learning. In the Architectural Design I course, Minecraft can be a potential tool for Project 1 to replace the sugar cube physical model as the Minecraft building blocks are modular and it can create various forms and interactions. For digital modeling projects, Revit has been employed as the main design tool and Minecraft can be an effective alternative tool to replace Revit in the early design phase. [8] Minecraft can be the preliminary design tool to help students gain an understanding of the scale, space, spatial and morphological relationships. This process has been implemented in the Architectural Design I class as seen in Figure 4.1.

This experimentation has been paired with rapid prototyping to enhance the understanding of spatial design. The department recently invested in 3d printers and supports cross-program workflow from digital modeling to rapid prototypes. This allows the students to explore design options with digital and physical models concurrently. The model can be easily translated to a printable file and the design options can be tested as shown in Figure 4.2

Figure 4.1 Using Minecraft as design and presentation tool

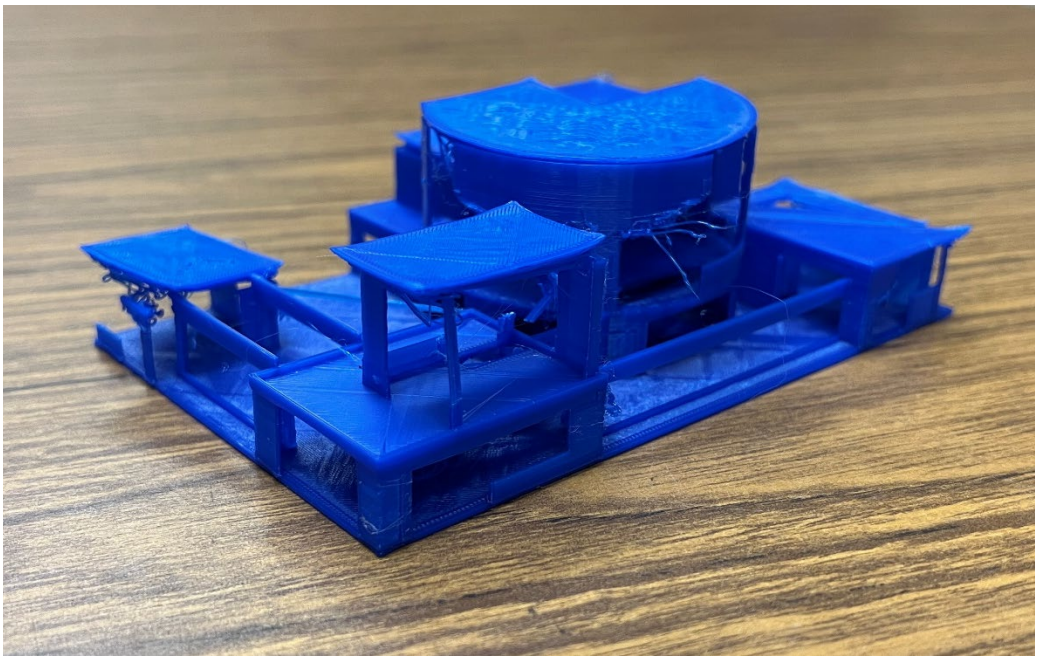


Figure 4.2 Rapid prototype

Next steps

- Conduct a case study of academic examples that incorporate VR learning in the architectural design curriculum.
- Investigate current VR implementation in the architectural and construction industries.
- Explore current VR training options and teaching strategies.
- Examine various VR gear and applications to determine pedagogical capabilities for architectural education.
- Identify funding sources to acquire VR gear for the experimentation.
- Define assessment model and data collection for using VR technology in the design courses.
    - Continue to assess the current experimentation of using available VR technology with experimental and control groups.

Conclusion

The emergence of VR, AR, and MR technology enables the architectural learning process to be more engaging, generative, iterative, immersive, and experiential. As the next generation of designers seek a more stimulating and innovative design platform, the student's familiarity with digital environments warranted the implementation of VR and gaming platforms in the current course as design and presentation tools. Although the sample size is small, the results of the survey suggest that the students favor using VR technology and value its benefits as a new design tool. This work-in-progress paper continues to gather data regarding the effectiveness of digital technology in the design process and strives to provide findings to the wider body of knowledge.

References

[1] B. Nisha, "The pedagogic value of learning design with virtual reality," *Educational Psychology,* vol. 39, no. 10, pp. 1233-1254, 2019.

[2] "Oxford Dictionaries," Oxford Dictionaries, [Online]. Available: https://www.oxfordlearnersdictionaries.com/us/definition/english.

[3] R. Oxman, "Digital architecture as a challenge for design pedagogy: theory, knowledge, models and medium," *Design Studies,* vol. 29, no. 2, pp. 99-120, 2008.

[4] J. Maina, "CAD AND BIM IN ARCHITECTURE EDUCATION: AWARENESS, PROFICIENCY AND ADVANTAGES FROM THE STUDENT PERSPECTIVE," *Gazi University Journal of Science Part B: Art Humanities Design and Planning,* vol. 6, no. 4, pp. 167-178, 2018.

[5] M. İ. Hemza Boumaraf, "Integrating 3D Printing Technologies into Architectural Education as Design Tools," *Emerging Science Journal,* vol. 4, no. 2, 2020.

[6] H. L. Rauf, S. S. Shareef and N. N. Othman, "Innovation in Architecture Education:," *Innovation in Architecture Education: Collaborative Learning Method Through Virtual Reality,* vol. 21, no. 16, pp. 33-40, 2021.

[7] J. Betz, "Assessing Creativity In Architectural Design: Evidence For Using Student Peer Review In The Studio As A Learning And Assessment Tool," in *ASEE 2009 Annual Conference & Exposition*, Austin, Texas, 2009.

[8] K. O'Connell, "Minecraft Architecture: What Architects Can Learn From a Video Game," 2 February 2016. [Online]. Available: https://redshift.autodesk.com/articles/minecraft-architecture.