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Teaching Landscape Construction Using Augmented Reality

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TEACHING LANDSCAPE CONSTRUCTION USING AUGMENTED REALITY

by

Arshdeep Singh

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ABSTRACT

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by

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Utah State University, 2018

Major Professor: Amanda Hughes, Ph.D.
Department: Computer Science

This thesis describes the design, development, and evaluation of an interactive Microsoft HoloLens application that projects landscape models in Augmented Reality. The application was developed using the Unity framework and 3D models created in Sketchup. Using the application, students can not only visualize the models in real space but can also interact with the models using gestures. The students can interact with the models using gaze and air-tap gestures.

Application testing was conducted with 21 students from the Landscape Architecture and Environmental Planning department at Utah State University. To evaluate the application, students completed a usability survey after using the application. Students also participated in a focus group. Results indicate that students were excited to use the application and found it helpful for learning landscape construction concepts. Some of the students found the application and the HoloLens device cumbersome to use, and they offered suggestions for how to improve the application. The thesis concludes with recommendations for future work.

(49 pages)

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Arshdeep Singh

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ACRONYMS

AR	Augmented Reality
ARA	Augmented Reality Application
VR	Virtual Reality
LAEP	Landscape Architecture and Environment Planning
SUS	System Usability Scale
USU	Utah State University
IRB	Institutional Review Board

CHAPTER 1
INTRODUCTION

Augmented reality (AR) is the integration of digital information with the user's real-world environment. Unlike virtual reality, which creates a completely artificial environment, AR uses the existing environment and overlays new digital information on top of it. Use of Augmented reality applications (ARAs) has helped in better understanding of concepts and encouraged innovation in domains like medical sciences, education, and health-care. AR has made it possible to present visualization models along with the subject of study to make the teaching process close to real-world scenarios; Imagine showing a video or a three-dimensional picture of a location to students while teaching subjects like geography or history or providing a virtual tour of the galaxy during an Astronomy class.

The AR application/tool that will be used for this research is the Microsoft HoloLens, a head-mounted device that supports AR applications. The HoloLens is the first self-contained, holographic computer, enabling users to engage with digital content and interact with holograms in the world around the users. The HoloLens uses hologram technology, which is a type of photography that records the light that every object naturally scatters. The light is then presented as a three-dimensional object known as a hologram. The interaction of virtual world elements along with the real-world makes the user experience pragmatic and immersive.

For this research, we used the HoloLens to create an augmented learning environment for a Landscape Architecture and Environmental Planning class at USU. The application will let students interact with visuals in the form of 3D landscape models. These models will be placed in an outdoor courtyard next to the landscape component that they describe. For example, a model of how the ground was prepared and the concrete poured to form a sidewalk might appear next to one of the sidewalks in the courtyard. Students can then walk around the courtyard and actively engage with the models, which we predict will help students better understand the concepts covered in class. Students can select, pick up and move the models immersed in the real world. Through the application, we aim to provide a real-time experience to students which will help to inculcate practical knowledge.

1.1 Research Question

This study aims to answer the following question:

How can Augmented Reality be used to provide students a real-world experience to learn Landscape Architecture and Environmental Planning concepts?

1.2 Research Overview

This research will develop an interactive Microsoft HoloLens application to project landscape models in the virtual and real world, which will help students have an interactive learning experience. These three-dimensional landscape models will provide a high-level description of design elements in the real world. Students can not only visualize these models in real space but can also interact with them by using gestures. This research is expected to deliver a real-time hands-on experience to students in classrooms that will supplement textbook reading.

1.3 Thesis Overview

This thesis document contains five additional chapters following this introduction. Chapter 2 contains the literature review, which describes ongoing research in the field of Augmented Reality. Chapter 3 describes the development of the HoloLens application and the environment setup for testing and running the application. Chapter 4 outlines the methods used for testing the application with students and for conducting the focus group. Chapter 5 summarizes the evaluation results of the data collected through observations, usability surveys, and a focus group. Chapter 6 outlines the discussion & conclusion of the study and concludes with the future work.

CHAPTER 2
LITERATURE REVIEW

While they have their differences, virtual reality (VR) and augmented reality (AR) both display virtual models and have the ability to alter a user's perception of the world. VR and AR are not new concepts, but the technologies that support them have seen significant advances in recent years. Consequently, researchers are examining their use in many different domains including education, healthcare, architecture, and planning. This chapter describes the relevant research literature regarding VR and AR and the contributions they have made in these domains. We first outline the related work in the field of VR.

2.1 Virtual Reality

VR is making an impact in the field of landscape architecture and environmental planning. A review was done on the use of virtual reality (VR) environments for research and teaching in the context of three disciplines: architecture, landscape architecture and environmental planning [1]. The review acknowledges that the use of the virtual reality expands a workflow that serves all three disciplines by providing an opportunity for planner-user interaction and for users' experience and feedback. Also, in architecture, engineering, and construction (AEC) the review of a proposed design is an essential step. Castronovo et al. found that 3D virtual reality in comparison to traditional 2D Computer Aided Design (CAD) or paper drawing helps user in efficient design review process [2]. In the study, researchers conducted design reviews for two different virtually immersive environments. They discovered that virtually immersive environments can play a vital role in the design process. Virtual 3D visualizations have become a common feature in landscape and urban planning design processes. One study examined developments in the field of landscape 3D visualization [3] and concluded that landscape visualization needs to move beyond the physically perceivable environment and focus on linking 3D visualizations with models. Also, the study emphasized the importance of investigating how to connect virtual or augmented realities with social realities. Our study of the HoloLens application we developed for teaching landscape architecture seeks to address these concerns by displaying 3D virtual models in the physical world next to the landscape elements they describe.

Using realistic virtual (3D) models is also affecting collaborative and participative approaches in the planning and design of landscape architecture [4]. For example, two different approaches were taken in a study on the on-demand dissemination of existing virtual 3D landscape models [5]. Researchers created and tested a touch-based interface with integrated mapping as well as a standard web browser interface on mobile phones. As per results from the study, using a standard web browser interface on mobile phones demonstrates the potential to reduce the complexity of accessing an existing 3D landscape model on-site to simply pointing a smartphone in a direction, loading a web page and seeing the relevant view of the model as an image.

VR has also been studied in the field of education. Researchers at Northumbria University investigated the role of VR and 3D computer modeling on learning and teaching [6]. In the study, researchers analyzed twelve VR and 3D computer modeling projects with academic staff to explore the usefulness and viability of 3D modeling in various subject areas. The study concludes that VR and 3D modeling technologies have the potential to improve and extend the learning process, increase student motivation and awareness, and add to the diversity of teaching methods. Spatial design is a crucial part of designing a VR and AR application. Chamberlain [7] describes the use of cutting-edge technology and games to grow spatial thinking, improve spatial design, and solidify landscape planning concepts within the classroom. Three different technologies (i.e., SimCity, CityEngine, and the Unity Gaming engine) combined with the Oculus Rift were used to explore if they would be effective at promoting learning and understanding spatial modeling methods. The study found that the tools used in this study provided a unique learning opportunity on simulation and analysis in a real-time virtual environment. Researchers from Indiana University–Purdue University Indianapolis used a virtual reality environment-based application called AVML (Advanced

Virtual Manufacturing Lab) to teach a graduate level course (CAD/CAM-Theory and Advanced Applications) [8]. AVML helps students with advanced multimedia lectures using intelligent virtual tutors, and it also provides hands-on training using a Computer numerical control (CNC) milling machine. The application was tested with students and researchers found that virtual reality provides better learning experiences to understand the course concepts. One study evaluated the impact of haptic-based VR 3D sketching interfaces versus conventional Computer Aided Design (CAD) tools on novice designer's cognition and design creativity [9]. Results found that haptic-based VR 3D sketching interfaces improve designers' cognitive and collaborative activities. The study also discovered that increasing the designer's engagement with the problem- and solution-space led towards more artifact maturity. Similarly, our study uses landscape architecture models and provides an opportunity to interact with those models to help students understand design concepts.

In healthcare, Virtual Reality (VR) is also making an impact on evidence-based design principles and practices for patient-centered healthcare environments. Researchers at the Purdue University Center for Healthcare Engineering have developed a VR mock-up of a hospital patient room to explore its efficacy for identifying how physical environment and design elements impact behavior, processes, and safety [10].

2.2 Augmented Reality

There are multiple organizations and researchers that are exploring the use of augmented reality in various domains and for diverse use cases. For example, Microsoft is working on building affordable inquiry and project-based activities to visualize data across science, technology, engineering, and math (STEM) curriculum [1]. NASA is using the augmented reality application (ARA) for a project named 'Sidekick'. Sidekick uses concepts of mixed and virtual reality to assist in future space exploration. The ARA lets the space station crews get the assistance they need from the remote teams, which will increase efficiency and reduce the amount of training required [2].

[1] https://www.microsoft.com/en-us/education/education-workshop/default.aspx

[2] www.nasa.gov/press-release/nasa-microsoft-collaborate-to-bring-science-fiction-to-science-fact

ARA's are also making a promising impact in the field of education. For example, HoloMuse is an AR application designed and developed by students at Wellesley College [11]. It helps art-history students to actively engage with archaeological artifacts in the classroom. In 2012, researchers conducted a cumulative study of research related to augmented reality, mixed reality, and education [8]. The study found that AR enables learners to engage in an authentic exploration of the real world as well as makes it easier for learners to experience the scientific phenomenon. For instance, Construct3D, a dynamic geometry, and mathematical system, lets students operate, measure, and manipulate virtual 3D objects to understand spatial relationships among them. ElectARmanual is an AR application designed to help students in the field of electrical education [9]. The application was built on the premise that engineering education should include both theoretical and practical knowledge. The purpose of the application is to provide students training and practice of installation of parts of the electric machine. For example, the application helps students through tasks like connecting wires and placing several components (e.g., coils, magnets, rotor, wide pole pieces, etc.) of the electric machine. ElectARmanual helps students to understand the instructions and explanations of the practice manual provided by the teacher in laboratory sessions. Our study uses ARA with 3D landscape architecture models which provides students experience visualizing and interacting with virtual models immersed in the real world. Based on prior research, we hypothesize that students will better learn landscape architecture concepts through these experiences engaging with the HoloLens application that we developed. One study considered the parental influence on children's development using augmented reality at the preschool level [12]. The study was based on five factors: motivation, knowledge, reading and writing, creativity and degree of satisfaction. The study concludes that parents found AR systems useful for their children in increasing comprehension and academic outcomes.

Augmented reality shows valuable impact in the field of healthcare as well. The Virtual Interactive Presence and Augmented Reality (VIPAAR) system developed at the University of Alabama at Birmingham assists surgeons in medical and surgical procedures [13]. By using the VIPAAR system, remote surgeons can view all the procedures and allow virtual interactions with local surgeons which provide additional support for complex procedures and high-risk surgeries.

CHAPTER 3
DEVELOPMENT OF SYSTEM

We developed an ARA which presents various 3-dimensional landscape models to a user, such as a staircase (see Figure 3.1) or a sidewalk using the Microsoft HoloLens device. The following steps were used to develop the system:

3.1 Designing Landscape Architecture and Environmental Planning Models

Three 3-dimensional models were designed by Andy Quebbeman, a graduate student under the guidance of Professor George in the Landscape Architecture and Environmental Planning at Utah State University. Sketcher a 3D model designing tool was used to design the models using various mesh elements using materials such as brick Antique, granite brown, aluminum, stone brushed khaki etc. Adding mesh elements provides the look of real-world models. The models along with the associated mesh files were later imported as assets in Unity, a 3D game development platform. The holograms/models were placed in the courtyard by specifying fixed coordinates. The courtyard is a square-shaped outdoor space located outside the Landscape Architecture and Environmental Planning Department at Utah State University. A user can interact with the holograms by running our application on the Microsoft HoloLens Device.

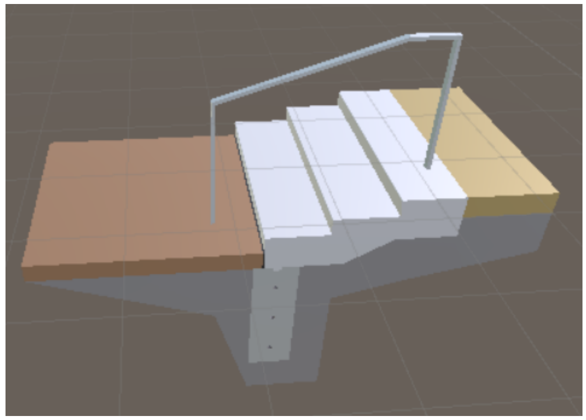

Fig. 3.1: Staircase Model.

3.2 Adding a Cursor

The cursor is a donut or torus shaped 3D element used to capture the user's gaze or help to indicate the current gaze of a user (see Figure 3.2). The cursor moves with the user's eyes, which allows the user to understand their gaze and acts as feedback to indicate which model or hologram will respond to user gestures. The user can select any of the model by placing the cursor element on that model. The cursor element is managed by using a C# script added to the game object of the system.

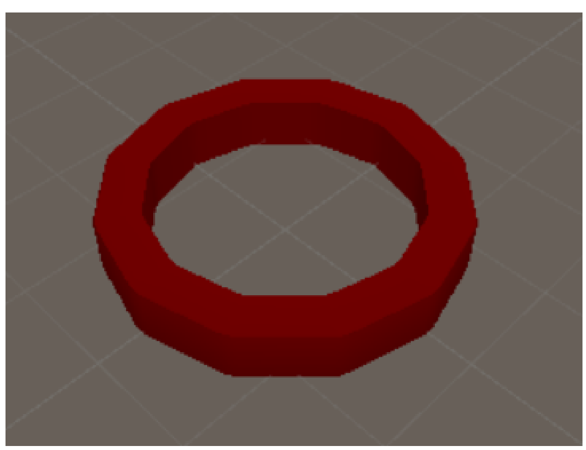

Fig. 3.2: Cursor Element.

3.3 Adding Gesture

The designed Landscape Architecture and Environmental Planning models were imported in the Unity platform to integrate those models with C# scripts and design elements. The C# scripts help to manage a cursor which points in the direction of the user's gaze and allows a user to interact with the holograms. Various design components, for instance a 'box collider' or a 'spatial mapping', were also added to the models which helps in proper selection and movement of models. A box collider is a basic cube-shaped collision primitive, that determines how the hologram interacts with other objects in an application. A box collider component is added to all the holograms in Unity which enables user to detect the holograms within a space in the application. The spatial mapping makes it possible to place the objects on a real surface. Visualizing the surfaces while placing or moving holograms helps the user to know where they can best place their holograms. The size and coordinates of the models were set in Unity to avoid overlapping among the models in the real-world while running the application. The following two gestures were implemented to interact with the models:

- **Gaze** : Point your head, not just eyes, to move the cursor and select the holograms in the app.(see Figure 3.3)

- **Air-Tap**: Works along with the gaze, to select the holograms (see Figure 3.4). Steps to implement the air tap are-

  - Gaze at the hologram with which you want to interact.
  - Hold your hand straight in front of you in the direction of your gaze.
  - Point your index finger in an upward direction.
  - Tap your figure down, then raise it quickly up again.

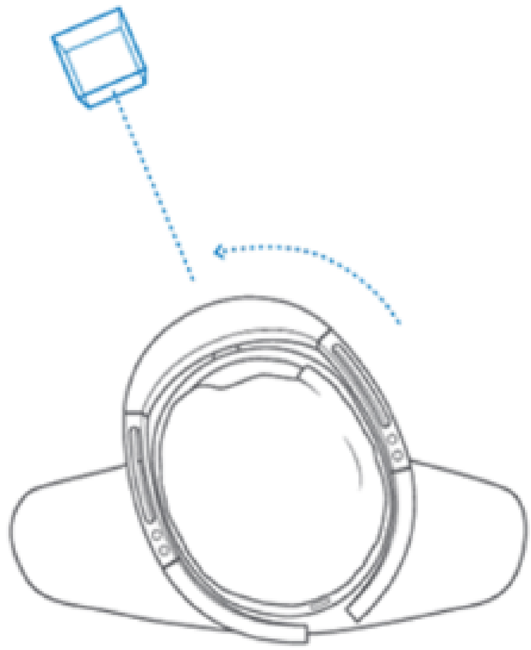

Fig. 3.3: Gaze Input.

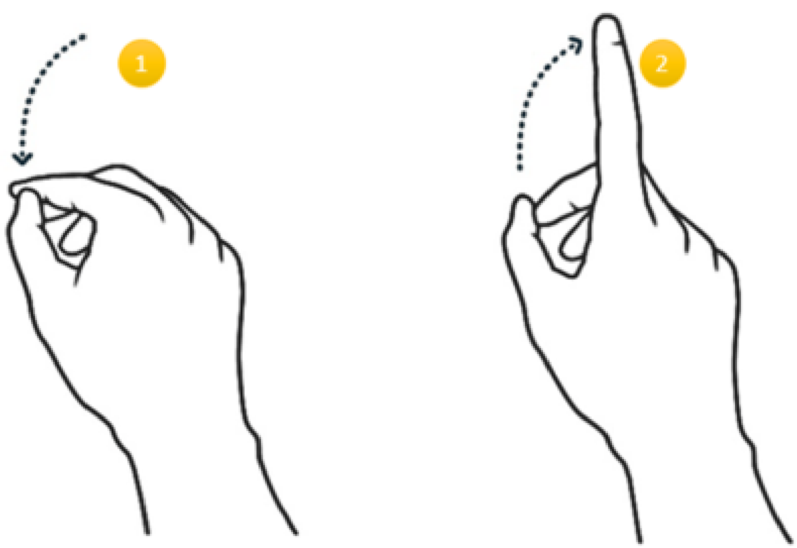

Fig. 3.4: Air Tap Gesture.

A HoloLens Emulator is used for testing the holographic app during development (see Figure 3.5). User inputs or gestures are stimulated by a keyboard, mouse or Xbox controller to test the working components of the app.

Fig. 3.5: HoloLens Emulator.

3.4 Environment

After testing the models on HoloLens Emulator, the models were placed in the courtyard by specifying fixed coordinates. Users can interact with the holograms by running the application through the Microsoft HoloLens Device. The courtyard is a square-shaped outdoor space located outside the Landscape Architecture and Environmental Planning Department at Utah State University (see Figure 3.6). The courtyard is surrounded by concrete walls and glass windows and includes various design components of Landscape Architecture such as sidewalks, trees, and storm drainage.

Fig. 3.6: Drawing of Courtyard Space

CHAPTER 4
EVALUATION OF APPLICATION

After development, the application was evaluated with students through two activities: user testing sessions and a focus group. Institutional Review Board (IRB) approval from USU was obtained prior to the application evaluation with the students. The students were asked to voluntarily participate for both the user testing sessions and the focus group activity.

4.1 User Testing

The evaluation of the application was done with students from the LAEP 3600 class of the Landscape Architecture and Planning department at Utah State University. The LAEP 3600 is an online class taught by Professor Ole Sleipness. The students were asked to participate in the research as a part of an extra credit assignment for the class. A total of 21 students participated in the study. For the assignment, students went to the courtyard where landscape models were placed using augmented reality in the HoloLens. A brief introduction on how to use gestures on the HoloLens was given to the students. By wearing the HoloLens device each student could visualize the designed models placed in the courtyard. Students tested the interaction of the models using gaze and air-tap gestures. The students were observed by the student researcher (Arshdeep Singh) while they were using the application. After testing the application each student was asked to complete a paper-based usability survey and quiz (see Appendix A). The quiz had questions related to the three models that students visualized in the application. Also, the students were asked if they would like to voluntarily participate in a focus group discussion.

Three models were implemented: a model of the French drain (see Figure 4.1), a model of the courtyard stairs section (see Figure 4.2), and a model of the seat wall (see Figure 4.3) in the courtyard.

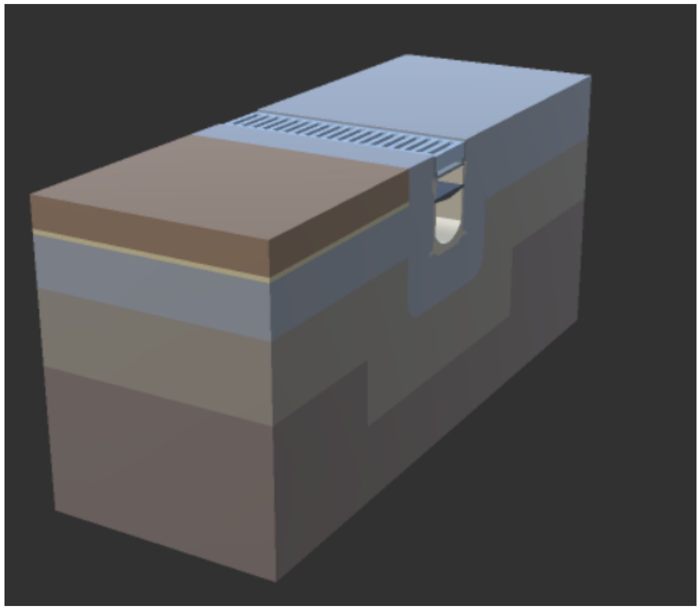

Fig. 4.1: French Drain Model.

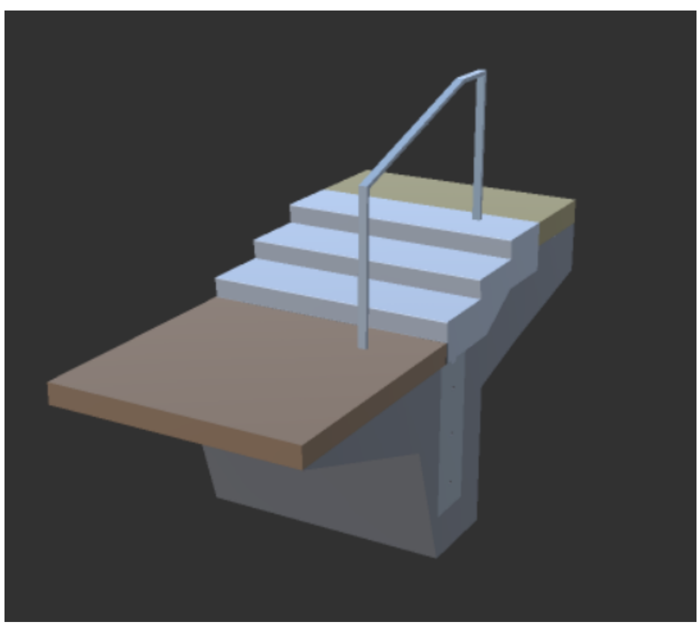

Fig. 4.2: Stair Case Model.

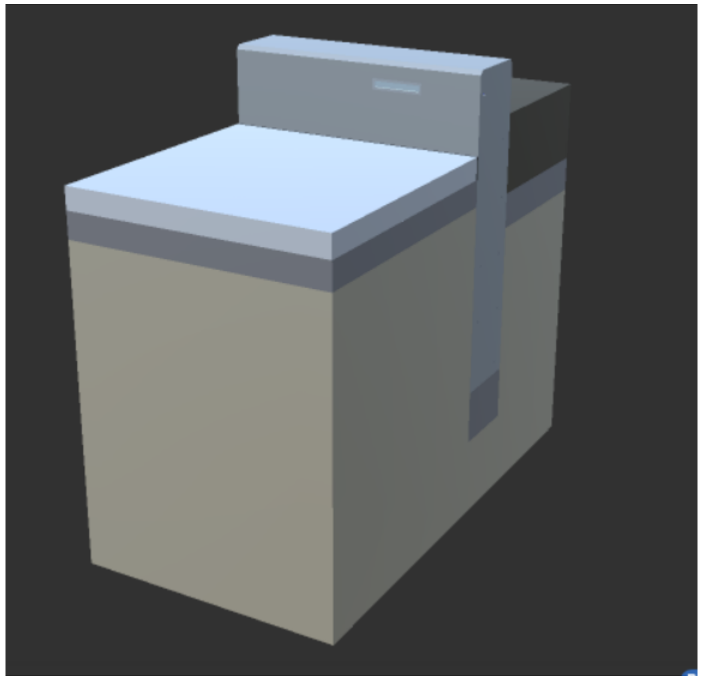

Fig. 4.3: Seat Wall Model.

The position of all the models was fixed in the courtyard. The students were asked to interact with each model and answer a quiz. The quiz consists of the questions related to the different layers associated with all the three models.

Each student got 10-15 minutes to interact with the models. During the testing, students were asked to try different gestures with various models. All the testing activities were video recorded.

4.2 Focus Group

Next, these same students were invited to participate in a later focus group to discuss issues and concerns about the features of the application (see Appendix B). A total of 9 students participated in the focus group discussion. The discussion lasted for about 1 hour and took place in a conference room housed in the Landscape Architecture and Environmental Planning department. During the session, one researcher (Arshdeep Singh) led the discussion while others (Professor Hughes, and Professor George) helped to guide the conversation as needed and took notes. The sessions were audio recorded and transcribed.

Results of the analysis of the focus group are described in the following chapter.

CHAPTER 5
EVALUATION RESULTS

This chapter reports on the evaluation of the HoloLens application developed for this study. Evaluation activities included participant observations, usability testing, and a focus group. The following sections outline the results of these evaluations.

5.1 Participant Observations

While the student participants were using the HoloLens application, a researcher followed the students and observed how they used the application. This researcher also helped the students learn how to use the device and answered any questions they had. The remainder of this section outlines what the researcher observed.

The students were excited to visualize models in the real world and they liked being able to move around the 3D models and observing them from different perspectives. Most of the students had already used VR devices, and after using the HoloLens device some of the students were pleased that they did not experience motion sickness as they had when using VR devices.

Many of the students had a difficult time when selecting the models using the air-tap gesture. While selecting the models, some of the students performed the air-tap gesture multiple times continuously because the gesture did not appear to work. One problem was that students didn't always make both the thumb and fore-finger fully visible when performing the air-tap gesture and so the HoloLens did not recognize the gesture. Another problem was that the air-tap gesture should be used only once to properly select or deselect a model; using the air-tap gesture multiple times on the same model results in selecting and deselecting the model simultaneously, which can make it appear that the gesture did not work. There is a slight delay between when someone performs the gesture and when there is visual confirmation that a model was selected. When a model is selected using the air-tap gesture, a spatial mapping in the form of wireframes of the physical space appears. By continuously performing the air-tap gesture, the students were unable to recognize the spatial mapping to move the selected models. The cursor element should be on the surface of the model to properly select a model using the air-tap gesture, but some of the students tried to select the models without having the cursor on the model's surface. Another selection difficulty occurred when students tried to place one selected model on other models using the air-tap gesture which sometimes resulted in selecting two models at the same time. While using the air-tap gestures with the HoloLens device, several students talked about how gestures in VR devices are more intuitive and much easier to execute as both hands are used. Many of the selection difficulties that students encountered can likely be attributed to it being the first time they were using the air-tap gesture. By the end of their test sessions, the students felt more confident using the air-tap gesture after some initial assistance.

Some of the students had problems mounting the HoloLens on their heads. For example, some of the students were not keeping the device tight enough to capture the best view of the models. When the device did not fit properly, the students would try to hold the HoloLens device with their hands while they were wearing it to capture the best view of the models. Some students felt the HoloLens device was too heavy to wear for longer time periods.

While using the application, students thought the application could be useful for understanding landscape design details at a physical location prior to the actual physical work. For instance, one student mentioned that having models of door handles in AR would help a designer to experiment with and decide on the position of the handles and the design elements of the handles before the actual physical design was complete.

Initially it was decided to give each student 10-15 minutes to interact with the models wearing the HoloLens device. However, some of the students used the device for 25-30 minutes as they felt more confident using the device and they were enjoying the experience.

5.2 User Testing Analysis

The usability survey (Appendix A) that students completed after using the HoloLens application assesses the usability of the application. The survey consists of 12 questions. The first 2 questions were about the familiarity of students with Augmented Reality and the Microsoft HoloLens, and the next 10 questions were taken from a standard usability measurement tool called the System Usability Scale (SUS)[1]. The questions in the SUS have five response options for each question, ranging from strongly agree to strongly disagree. After testing the application, each student was asked to complete the survey. All 21 students finished the survey. The results of the survey are reported below:

5.2.1 Familiarity with Augmented Reality

Only 4 of the 21 students were familiar with the concept of Augmented reality (AR) prior to participation in the study(see Figure 5.1). For the other 17 students, it was their first time using an AR system. All of the students were using the Microsoft HoloLens device for the first time.

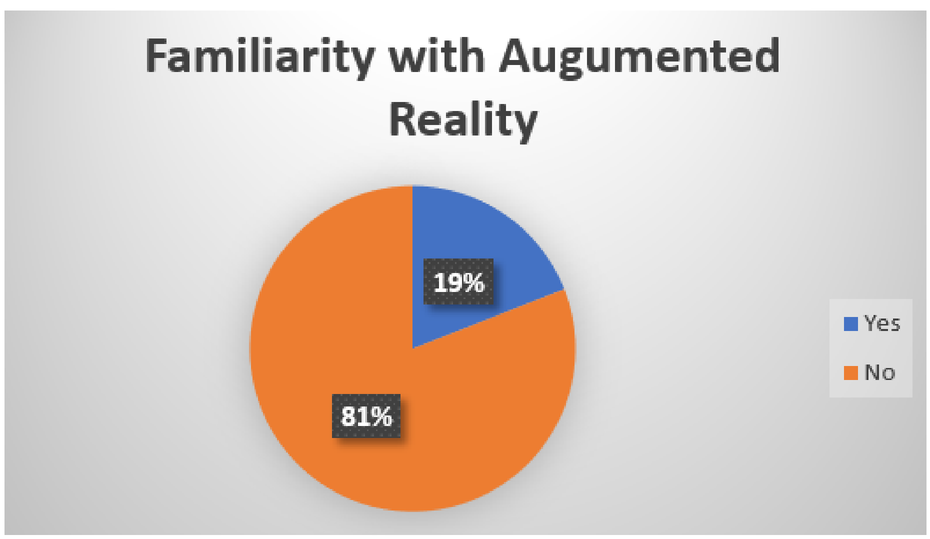

Fig. 5.1: Percentage of Students Familiar with AR.

5.2.2 Application Usability

There were three questions in the survey related to the user's experience after using the application. The students were excited after interacting with the models using the air-tap

[1]https://www.usability.gov/how-to-and-tools/methods/system-usability-scale.html

and the gaze gestures. The students were able to quickly learn the gestures with some initial assistance.

The charts below represent the responses of the students regarding the usability of the application:

- **Unnecessary Complexity**

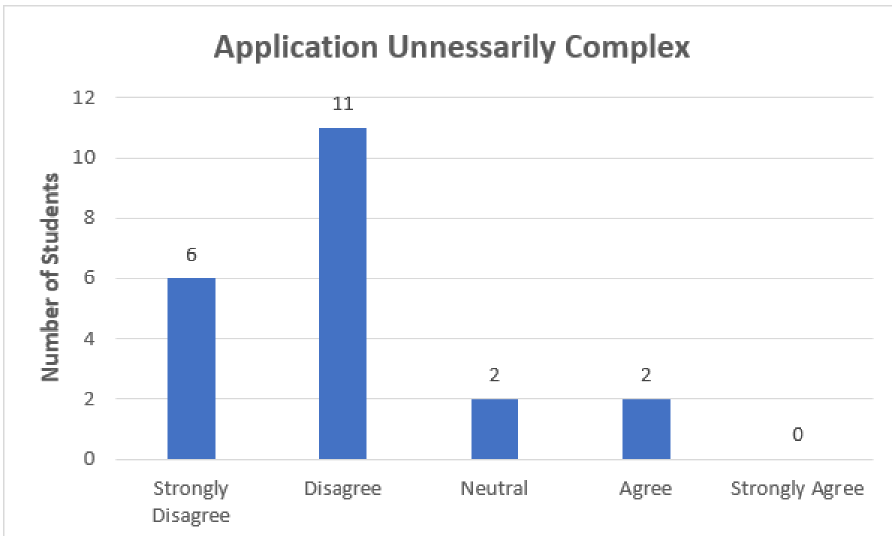

Fig. 5.2: Student Responses for Whether the Application Was Unnecessary Complex.

Most of the students did not find the application unnecessarily complex (see Figure 5.2). There were, however, 2 students that did feel that the application was unnecessarily complex.

- **Easy to Use**

A little over half (11 of 21) of the students agreed that the application was easy to use (see Figure 5.3) . Again, none of the students marked the response strongly disagree. 8 of the student's responses were neutral. Also 2 students marked disagree. Some of the students initially faced difficulties distinguishing among the layers of the models and using the air-tap gesture for selecting the models. A more detailed description of these difficulties is discussed later in the focus group data analysis.

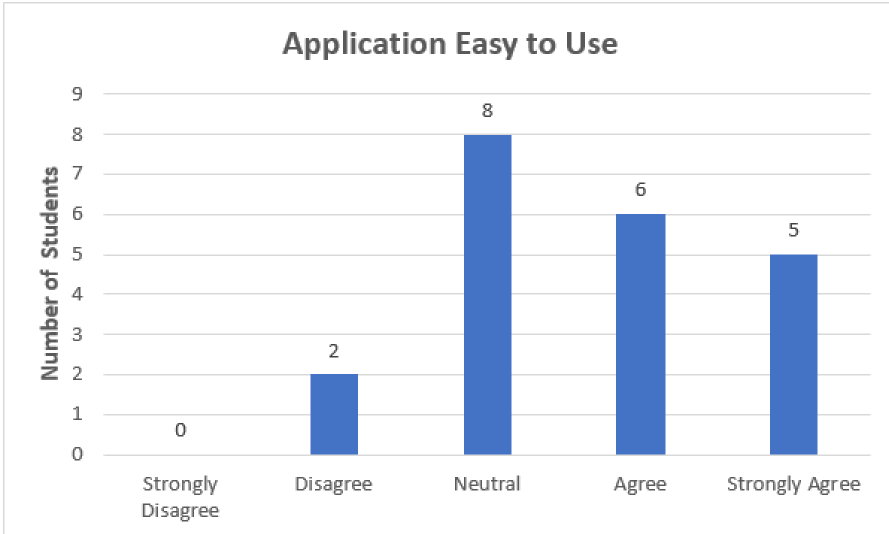

Fig. 5.3: Student Responses for Whether the Application Was Easy to Use.

- **Cumbersome to Use**

  None of the students marked strongly agree when assessing whether the application was cumbersome to use (see Figure 5.4). Most of the students (15 strongly disagree and disagree answers) did not feel that the application was cumbersome to use.

  The above three questions are related and contribute to understanding the usability of the application. Results showed that the students responses and attitudes regarding the usability of the application were mostly positive. There were, however, a significant number of neutral responses and a few negative responses that we tried to better understand in the focus group discussion with the students (described later in this chapter).

5.2.3 Integration of Application Functions

Integration of various functions was also tested as a part of the usability of the application. The results show that 1 and 12 out of 21 students strongly agreed and agreed respectively that the various components of the application (such as models position, gestures etc.) were well integrated (see Figure 5.5). Six and two students marked responses neutral and disagree respectively.

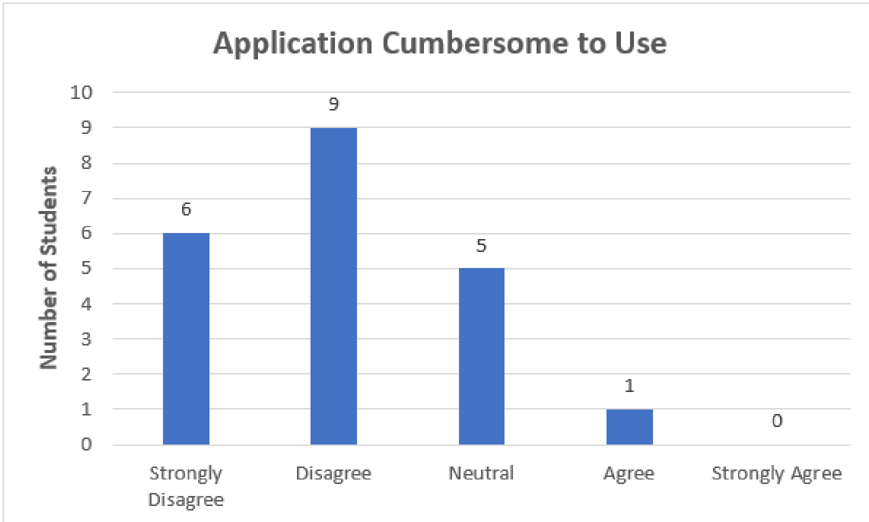

Fig. 5.4: Student Responses for Whether the Application Was Cumbersome to Use.

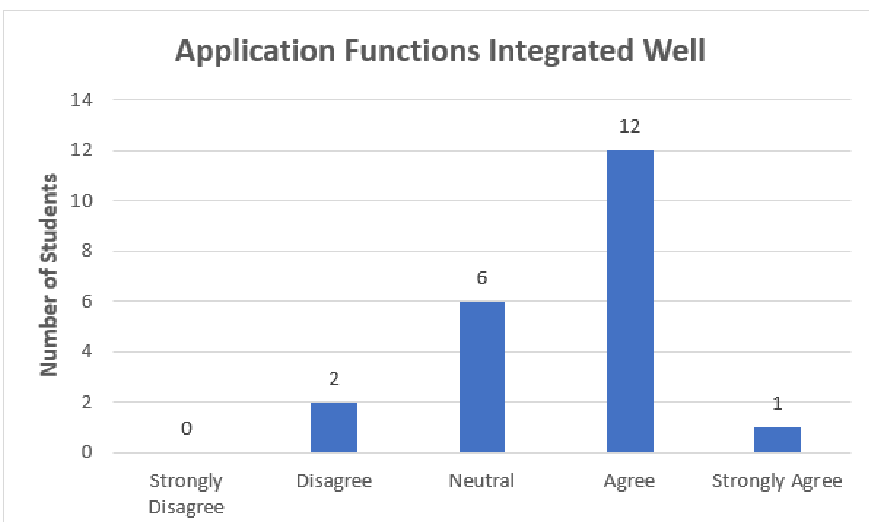

Fig. 5.5: Student Responses for Whether the Application Functions Were Integrated Well.

5.2.4 Need for Technical Assistance

In the survey, the students were asked whether they would need technical assistance to help them use the application. Almost half of the students (10 of 21) agreed that they would need this kind of assistance (see Figure 5.6). From the other half, 8 of the responses are neutral. Two and one students marked disagree and strongly disagree in the responses. All the students were using the Microsoft HoloLens device for the first time, so that might explain why many of the students indicated they would need technical assistance to use the application.

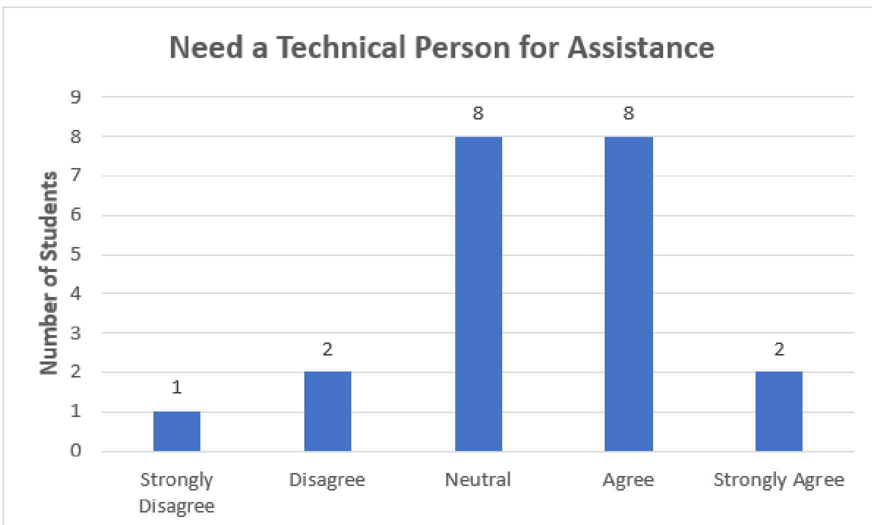

Fig. 5.6: Student Responses for Whether They Needed Technical Assistance to Use the Application.

5.2.5 Likely to Use the Application Frequently

In the survey, the students were asked whether they were likely to use the application frequently. Ten and six students marked agree and strongly agree respectively, which is approximately 76% of the total responses collected (see Figure 5.7). Three of the responses are neutral and 2 students marked disagree.

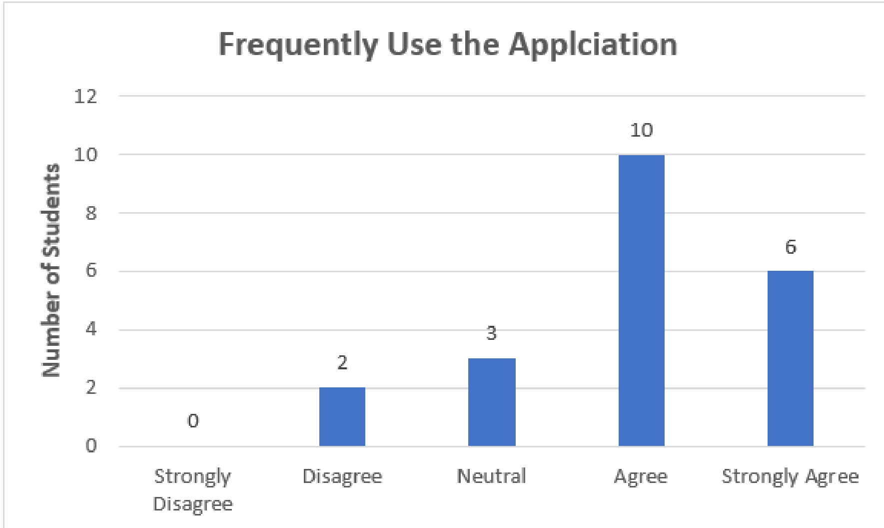

Fig. 5.7: Student Responses for Whether They Would Frequently Use the Application.

5.2.6 Overall System Usability Score

As per the system usability guide[2] the overall score for each participant can be calculated by using the following steps:

- Each question's score contribution will range from 0 to 4.
- For questions 1, 3, 5, 7, and 9, the score contribution is the scale position minus 1.
- For questions 2, 4, 6, 8 and 10, the contribution is 5 minus the scale position.
- Multiply the sum of the scores by 2.5 to obtain the overall value of application usability.

The overall value obtained after following the above four steps represents the usability score of each participant out of 100. The chart below represents the calculated overall score for each student.

As per the system usability guide, a score above 68 is considered above average and anything below 68 is considered below average (see Figure 5.8). Out of 21, 7 responses are above average, the other 14 scores are below average. As all the students were using

[2] https://www.usability.gov/how-to-and-tools/methods/system-usability-scale.html

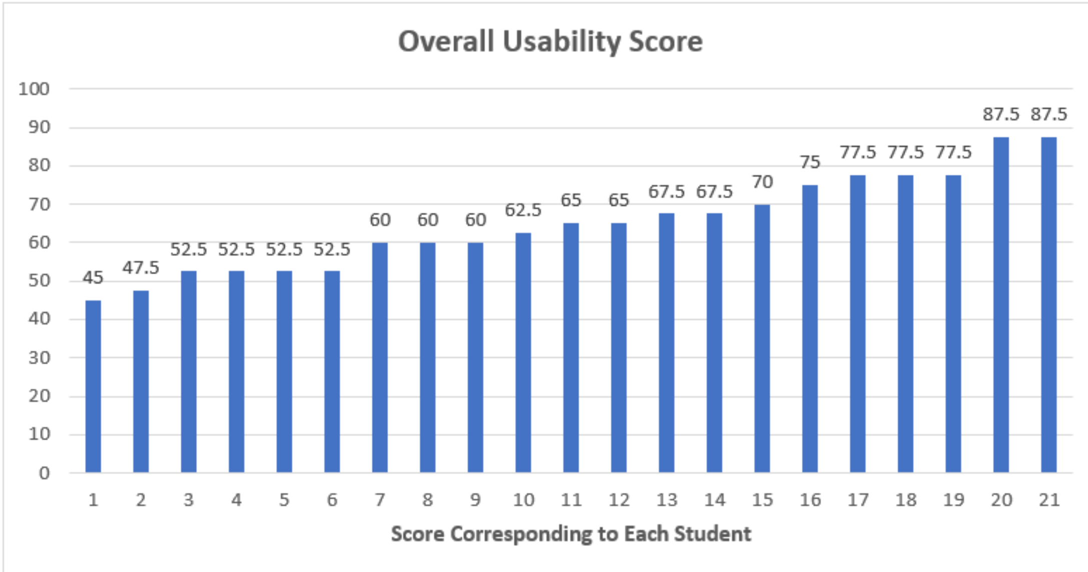

Fig. 5.8: The Overall Usability Score for Each Student Participant.

the Microsoft HoloLens for the first time and 17 out of 21 were visualizing the models in Augmented Reality for the first time, this might explain some of the below average scores. Clearly there are some usability issues with the application, but the survey was limited in its ability to identify specific issues. To better query and understand the usability challenges of the participants, a focus group was held.

5.3 Focus Group Discussion Analysis

During the focus group, the students were asked questions related to the application's usability and each student was given the opportunity to express his/her opinions. The results are organized around the main questions from the discussion:

5.3.1 What Did You Like About the Application?

The students were excited to visualize the 3d models in Augmented Reality (AR) and there were many things they liked about the application. Some of the students had already used Virtual reality (VR) earlier in their course work. So, they often compared the concept of AR with VR. In AR a user can visualize virtual objects immersed in the real world.

For instance, the students liked that they could visualize the real world along with the 3d models. They also liked that they could move closer to each of the models and view the different layers of the models in 3d and from different angles. Students were excited when they could move the models by using the air-tap and gaze gestures. They also asked questions about what other types of gestures could be implemented in the future. Finally, the students also liked that they could place the models on real-world objects. For instance, one of the students first selected one of the models and then placed the model on a sitting area in the courtyard space.

The students found a major advantage of using AR was that they could visualize models in an actual site or physical location which later might be used for a new design. By using the HoloLens, they could easily identify various design related components and design details which could help them in actual physical design at a site.

5.3.2 What Did You Dislike About the Application?

The students mentioned that the colors of the models were hard to differentiate. Because the models used lighter colors for the different layers there was less contrast among the various layers of the models. If some of the layers could be darker in color, that would help users of the system to distinguish among the materials of the models more easily. Sketcher, a 3d-model designing tool, was used to design the models and it automatically chooses colors for different materials. The students in the focus group were familiar with the tool, so they could understand why the models were light in color combination. For future work, it will be important to choose colors with more contrast when designing models for visualization with the HoloLens application.

The students also mentioned problems with using the air-tap gesture. Some of the students faced difficulty in properly selecting the models using the air-tap gesture. For selecting a model, a user has to first point the cursor on the model to be selected by gazing at the model. After having the cursor on the model, the user has to use the air-tap gesture to select that model. There is spatial mapping around the model which helps a user to see that the model is selected and ready to move along the spatial mapping. However, several students indicated that they faced difficulties while selecting the models and it would be better if the color of the selected models could be changed, which would give a user a clearer indication that the model is selected.

While comparing Augmented Reality (AR) with Virtual Reality (VR), the students mentioned differences in the field of view. The HoloLens provides limited field of view compared to VR devices, such as the Oculus Rift, that the students had used earlier. However, the Microsoft corporation is working on improving the field of view on the HoloLens[3]. Some of the students had difficulty adjusting the HoloLens device on their head to capture the best view of the models. As the HoloLens works with a user's gaze, the device should be properly head-mounted and needs to be closer to the eyes for optimal performance.

5.3.3 How Could The Application Be Improved?

The above-mentioned student's opinions on what they dislike about the application help inform future improvements for the application. In addition, focus group participants offered several ways that the application could be improved with additional features. Several students asked if the models could be exploded and then put back together into their constituent parts. The students felt that breaking the models apart would help them to better visualize and understand how the different components of a model are designed and fit together. The focus group also thought it would be useful to add label names to the different layers of the models. Labeling the layers would help students to better understand the different layers of the models.

Many of the students had not seen the specific models used in testing before and thus, they did not always understand what they were viewing when they looked at the models through the HoloLens. In the future, students would like to know more about what they were going to see with the HoloLens to help them better understand the models and their design details. For instance, if the students were shown 2d models in the classroom before using the application, that would help them to understand those same models while visualizing them in 3d using the application.

[3] hololens.reality.news/news/microsoft-has-figured-out-double-field-view-hololens-0180659/

The students were excited about the prospect of using similar applications for other courses in the future. For instance, the students mentioned the Materials class (one of the class taught at LAEP department at Utah State University) as a possible candidate for the application. Using an AR application could help students visualize and learn design components related to various materials for that class. The students also mentioned using AR applications when working with clients onsite at a physical location. For example, an AR application could help them to demonstrate a landscape design with clients before the work to implement the design had been done. This feature could help them pitch different design options and also help them obtain better feedback on the design from their clients. Seeing all these future possibilities, the students were excited about using AR as part of their classroom learning.

Student feedback offered during the focus group gave us confidence about the future usage of the application as well as provided us feedback about how the application can be improved for future use.

CHAPTER 6
DISCUSSION & CONCLUSION

This chapter begins by summarizing and discussing the results of the study. We then offer broader implications for the research and present future work.

In this research, we designed and developed an Augmented Reality application for students using the Microsoft HoloLens device. The application enables students to visualize and interact with 3d Landscape Architecture models in Augmented Reality.

The application was evaluated with students from the LAEP 3600 class of the Landscape Architecture and Environment Planning department at Utah State University. The evaluation had three components: 1) observations of the student participants as they used the application, 2) a usability survey that students completed after using the application, and 3) a focus group discussion.

The evaluation of the application revealed strengths and weakness of the application. For example, the students liked the concept of Augmented Reality (AR) as they were able to visualize the 3d models immersed in the real world. The students also liked to interact with the models using gestures. Students saw potential for the application in working with clients on landscape designs and for designing and visualizing models that later can be used to design actual models at a physical location. Also, the students showed interest for using similar applications in the future for other courses.

Students also identified limitations of the application. Examples include the lack of color contrast in the models, the challenge of using the air-tap gesture to select a model, the limited field of view, and the difficulty in properly mounting the headset for optimal visualization. Most of these limitations can be addressed in future work.

6.1 Comparison of AR and VR

A common theme in this study was how the student participants compared AR to

VR. Most of the students who participated in the study were already familiar with the concept of VR. Some of these students had even used VR devices such as the Oculus Rift for other courses. Due to the similarities between VR and AR devices, students who had prior experience with VR found it natural to compare their experience with AR.

The students noted several differences between VR and AR. By using an AR application the students were able to visualize the real world along with the virtually designed models but in VR a user is in a virtual space and unable to visualize the real world. The students found that visualizing the real world in an AR application made them less motion sick compared to VR applications. To interact with a system, both AR and VR applications use human gestures. The study found that AR HoloLens gestures are not as intuitive when compared to other VR devices. Some of the difficulties faced by the students were trying the air-tap gesture multiple times to select the models and placing one model on top of another model using the air-tap gesture which resulted in selecting two of the models at the same time. In VR, students reported that the gestures seem to work more consistently and are more intuitive as both hands are used for interaction. The students needed some assistance to properly implement the air-tap gesture and to properly position the device on their head. This assistance explains why there was a high number of neutral (8 responses) and agree responses (8 responses) for usability survey question regarding whether the students felt they would need technical assistance to use the application. The initial help that students needed with the air-tap gesture also likely explains the high number of neutral responses for the usability survey questions regarding whether the application was easy to use (8 neutral responses) and whether the application was cumbersome to use (5 neutral responses). These initial struggles with the interface likely account for the lower usability scores for the application. We suspect that most of these struggles can be attributed to students using a new system for the first time. We would expect these usability scores to improve with further use. The concept of AR encapsulates both virtual reality and the real world which provides a user with an interactive real environment. As per the study, the participants liked the concept of AR in comparison to VR, but a primary concern was the lack of more intuitive user gestures for interacting with AR devices.

6.2 Potential Use of Similar AR Applications

In the study, students suggested that similar AR applications could potentially be used in two different areas: 1) for other courses and 2) for professional landscape designers working with clients. Results from the usability survey also show that most of the students (76% of the responses) felt they would be likely to frequently use a similar kind of application in future.

AR applications could be a part of classroom learning for other courses to facilitate students to better understand the design details and concepts using models in real space. For instance, the students mentioned using similar applications for a materials class in the Landscape Architecture and Environmental Planning department.

AR automatically maps a user's surroundings, which helps a user to identify design elements at a physical location. An AR application could be used by a designer to visualize the models and identify design components prior to the actual physical design. Designers can also visualize how the proposed design looks in the real world and what changes would be required before starting the physical work, which could help reduce time and cost.

AR applications could also be a part of a proposed design review while working with clients. Using an AR application with a client at a physical location will help to obtain feedback prior to the actual physical work.

6.3 Understanding Landscape Models

The current application uses three 3D landscape architecture models and provides users the ability to visualize and interact with those models. The coordinates of the models were fixed initially and the students were asked to visualize the models by walking around and interacting with them using gestures. The application helped the students to understand the design details of the models immersed in the real world. While the models were seen as helpful, students identified several ways that the models and their visualization could be improved to increase learning. Students suggested that the application could add label names to the different layers of the models. The label names would help a designer or a student while using the application at a physical location to better understand the model components and to identify which layer might needs to be modified. Students also wanted to have the ability to explode the models into their constituent parts and then to put them back together again. They imagined that this feature would facilitate learning more about the interior design details of the models. It would also help users better understand how the various layers of the models fit together. As already discussed, students also wanted to have more intuitive gestures to interact with the models.

Understanding of the design details of the models is an essential step in landscape architecture planning. AR provides the opportunity for students and designers to visualize and understand the design components of landscape architecture models in the real world. Using a similar AR application would help designers to have a deeper understanding of the design details prior to implementing an actual physical design, resulting in a potential reduction in time and cost by avoiding rework.

6.4 Future Work

In the future, the application can be enhanced by taking into consideration student feedback. Tasks for future work are listed below:

- New models can be designed using darker color materials or by using greater color contrast between the layers to help users easily identify design details of the models.
- Prior information regarding the models that users are going to view in AR can be provided to the users to help them better understand the design concepts of the models.
- New models can be added to the application.
- The application could be changed to allow the user to break apart a model using the air-tap gesture. This feature will help users to better understand the inner design details of the models.

We are thankful to every student for their participation and thoughtful views regarding the application. This research demonstrates that by using Augmented Reality as a part of classroom learning, students will be better equipped to visualize design concepts in real-world settings and will inculcate practical knowledge.

REFERENCES

[1] M. Portman, A. Natapov, and D. Fisher-Gewirtzman, “To go where no man has gone before: Virtual reality in architecture, landscape architecture and environmental planning,” *Computers, Environment and Urban Systems*, vol. 54, pp. 376 – 384, 2015. [Online]. Available: http://www.sciencedirect.com/science/article/pii/S019897151500054X

[2] F. Castronovo, D. Nikolic, Y. Liu, and J. Messner, “An evaluation of immersive virtual reality systems for design reviews,” in *13th International Conference on Construction Applications of Virtual Reality (CONVR), London, Oct*, 2013, pp. 30–31.

[3] E. Lange, “99 volumes later: We can visualise. now what?” *Landscape and Urban Planning*, vol. 100, no. 4, pp. 403–406, 2011.

[4] N. Gu, M. J. Kim, and M. L. Maher, “Technological advancements in synchronous collaboration: The effect of 3d virtual worlds and tangible user interfaces on architectural design,” *Automation in Construction*, vol. 20, no. 3, pp. 270–278, 2011.

[5] L. Gill and E. Lange, “Getting virtual 3d landscapes out of the lab,” *Computers, Environment and Urban Systems*, vol. 54, pp. 356–362, 2015.

[6] M. Horne and E. M. Thompson, “The role of virtual reality in built environment education,” *Journal for Education in the Built Environment*, vol. 3, no. 1, pp. 5–24, 2008.

[7] B. Chamberlain, “Crash course or course crash: Gaming, vr and a pedagogical approach. proceedings of the 2015 digital landscape architecture conference. anhalt, germany,” 2015.

[8] H.-K. Wu, S. W.-Y. Lee, H.-Y. Chang, and J.-C. Liang, “Current status, opportunities and challenges of augmented reality in education,” in *Computers and Education*, 2017.

[9] J. Martin-Gutierrez, P. Fabiani Bendicho, W. Benesova, M. Meneses Fernández, and C. Mora, “Augmented reality to promote collaborative and autonomous learning in higher education,” 01 2015.

[10] M. J. L. G. K. A. Dunston P.S., Arns L.L., “An immersive virtual reality mock-up for design review of hospital patient rooms. in: Wang x., tsai j.jh. (eds) collaborative design in virtual environments. intelligent systems, control and automation: Science and engineering, vol 48. springer, dordrecht,” 2011.

[11] C. Pollalis, W. Fahnbulleh, J. Tynes, and O. Shaer, “Holomuse: Enhancing engagement with archaeological artifacts through gesture-based interaction with holograms,” in *Tangible and Embedded Interaction*, 2017.

[12] A. Cascales, D. López, and M. Contero, “Study on parent’s acceptance of the augmented reality use for preschool education,” vol. 25, pp. 420–427, 12 2013.

[13] J. Herron, "Augmented reality in medical education and training. journal of electronic resources in medical libraries," pp. 51–55, 02 2016.

APPENDICES

APPENDIX A

System Usability Survey

Appendix A: User Experience Survey

Are you familiar with Augmented reality? If yes, please explain.

Have you used the Microsoft HoloLens before? If yes, please describe briefly.

Fig. A.1: System Usability Survey

	Strongly Disagree 1	2	3	4	Strongly Agree 5
1. I think that I would like to use this application frequently					
2. I found the application unnecessarily complex					
3. I thought the application was easy to use					
4. I think that I would need the support of a technical person to can use this application					
5. I found the various functions in this application were well integrated					
6. I thought there was too much inconsistency in this application					
7. I would imagine that most people would learn to use this application very quickly					
8. I found the application very cumbersome to use					
9. I felt very confident using the application					
10. I needed to learn a lot of things before I could get going with this application					

APPENDIX B

Focus Group Script

Appendix B: Script for Focus Group

Hello. My name is Arshdeep Singh. I would like to start off by thanking each of you for taking time to participate today. We will be here for about an hour. The reason we are here today is to gather your opinions and attitudes about the usability of Augmented Reality application(ARA) for Landscape Agriculture and Architecture models.

I also would like you to know this group will be audio recorded and is strictly voluntary. The identities of all participants will remain confidential. The recording allows us to revisit our discussion and analyze areas of improvement for the application. Does anybody have any question before we proceed with the discussion?

Ques 1) How was your experience with the Application?

- What did you like about the application?
- What did you dislike about the application?
- Where there any tasks that were challenging?

Ques 2) Did the system help you to better understand the concepts covered in the class? Why or why not?

Ques 3) Could you imagine using the application for other courses? What courses and how would it work?

Ques 4) How could the application be improved?

Ques 5) Is there anything else you would like to discuss concerning the application?

Again, thank you very much for your participation today. We really appreciate your help.

Fig. B.1: Focus Group Script