Master's thesis on Cognitive Science
University of Osnabrück

Virtual Reality as a Tool for Improving Study Performance: A Comparison of Familiar and Novel Classroom Environments

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Abstract

This research aimed to investigate the impact of virtual reality (VR) technology on students' understanding of educational material by comparing their experiences in a familiar environment, a replica of a university classroom, to a novel virtual environment. The results indicate promising advantages of utilizing VR technology to enhance the learning process. The virtual replica of the real classroom demonstrated participants' higher scores in the knowledge assessment. The Likert survey revealed that participants from the familiar environment generally had higher average scores in questions related to realism, immersiveness, likeliness to use the technology in the future, and the feeling of the presence of other students. However, statistical analysis did not confirm a clear relationship between these factors and educational performance. Interviews with participants provided further insights, highlighting positive and negative impression of the VR environment. The implications of this research for education include the significance of recognition and familiarity in designing educational environments. Future research should explore the relationship between recognition, familiarity, and educational outcomes in VR, consider other factors that may influence educational performance, and focus on improving interactivity, realism, and engagement within VR environments.

Keywords: Virtual Reality; Education; Learning; Immersion; Unity VR; Virtual classroom; Oculus Quest 2; Recognition; Familiarity

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Chapter 1

Introduction

Virtual Reality (VR) technology allows to create unique virtual environments by immersing users in alternate realities. Such immersive environments are used for many purposes: not only for entertainment but also for the subject of various studies. Therefore, more and more companies such as Meta, Qualcomm, Apple, Microsoft, and many others are investing in research. Such interest from the public and companies can be explained by the increased availability of a variety of VR devices in the market, growing developer communities, and open access to sophisticated software and development tools (Siriborvornratanakul, 2016). Even though VR technologies are no longer something new, they have been used in education relatively recently. This thesis focuses on the development of a single-user virtual reality software prototype to improve students' understanding of online materials such as pre-recorded lectures and presentations in a simulated lecture environment. This research paper aims to facilitate an understanding of the potential benefits and limitations of virtual reality in education by examining the impact of virtual reality environments such as classrooms on learning outcomes and user experience. Furthermore, consider the development of such technologies used for self-improvement or repetition of the covered material. This is interesting because it paves the way for research that can help understand how the perception of components such as environmental recognition, interactivity, comfort, and the sense of presence affect educational performance in virtual reality. However, the effectiveness of VR in education is still an area of ongoing research, and some problems and limitations need to be addressed.

1.1 Motivation

The increasing global interest in VR potential inspires the author of this study. Incorporating virtual reality technologies in education to assess its impact on enhancing academic performance makes it a crucial task for this research. Every year, because of some great researchers exploring VR, this field has led to massive improvements of immersive technics. Several studies have shown mixed results on the impact of virtual reality on learning outcomes, with some studies indicating significant improvements (Loup, Serna, Iksal, & George, 2016; Johnson-Glenberg, 2018; Slater, 2018). Others reported no significant positive impact or even negative relation between virtual reality and traditional learning methods(Huang, Luo, Yang, Lu, & Chen, 2019; Lavoie, Main, King, & King, 2021). It is worth keeping in mind that virtual reality can have its limitations when it comes to education. There can be some costs involved, along with technical challenges and the need for specialized guidance. However, the benefits can be certainly impressive. With virtual reality, students can experience realistic remote interactions, which can help to boost their engagement, motivation, and retention of important knowledge. Due to the popularity of VR in entertainment, there is a tendency that fun and almost impossible virtual locations are causing more interest in learning in VR, but this thesis is motivated to find out if this is the case. Thus, this research proposes to look at virtual environments in terms of recognition and recognizability, concepts not previously explored in the field of education. Based on this, this work highlights the following hypotheses:

- **Null Hypothesis:** There is no significant difference in the understanding of educational material between the participants in the novel virtual classroom and those in the familiar virtual classroom.

- **Alternative Hypothesis:** Participants will have a greater understanding of educational material in the familiar virtual classroom compared to the novel virtual classroom environment.

Therefore, this thesis aims to create and test immersive software by studying the outcomes of participating in a simulated VR lecture, which may answer some of the questions that exist regarding VR research and how various immersion factors can be suggested as evidence to support claims of VR benefits. Moreover, this thesis tries to answer three research questions:

- “How does the virtual environment affect participants' understanding of the learning material?
- “How do participants perceive the virtual environment in terms of its realism, immersion, interaction with educational content and other characteristics?”
- "What are the participants' subjective experiences and feedback on the VR classroom?"

1.2 Scope and Limitations

The purpose of this study is to evaluate the effectiveness of virtual reality (VR) technology as an educational tool. The study aims to examine relevant research on the potential benefits of using virtual reality technology in education, such as realism, immersion, increased motivation, ease of interaction, comfort, sense of presence and facilitating better retention of information. This review can help correctly implement these characteristics when creating a prototype.
Besides, it is important to recognize the inherent limitations of this study. First, the availability of resources and time constraints create some obstacles. Second, considering the complex nature of virtual reality development, the present study will narrow its focus to two virtual classrooms - each with a limited number of participants. Furthermore, the study will center around a particular "virtual lecture topic," which may limit the generalizability of the findings to other subject areas and participants' backgrounds. In addition, this study will primarily examine the

short-term effects of using virtual reality as an educational tool and may not examine in detail the long-term effects of this technology on learning outcomes.

Another notable limitation of this study relates to the possibility of bias, as the researcher takes on the dual role of VR application developer and facilitator. To alleviate this limitation, the researcher will use several measures and methods to collect and analyze data, including pre- and post-questionnaires, Likert scales, and interviews. Using such strategies, the study aims to ensure comprehensive data collection and minimize the impact of technical errors during experiments. Moreover, these limitations will be explicitly acknowledged and discussed in the study report to ensure transparency and accuracy of the results.

1.3 Overview of the Thesis

The introductory chapter provides an overview of the research topic, clarifying the background and rationale behind the study, as well as defining the research scope and outlining its limitations.

Next chapter presents a comprehensive literature review, exploring previous studies on how VR can be used in educational institutions. The review encompasses an examination of the advantages and challenges associated with integrating VR into teaching and learning processes. Furthermore, existing literature concerning the influence of virtual environments on learning outcomes is summarized.

Third chapter clarifies the implementation phase of the research, presenting an overview of the prototype and providing technical insights into the employed software. Furthermore, the chapter explores the design of the virtual environment and user experience aspects, while also addressing the encountered challenges throughout the developmental process.

The experimental design is explained in the fourth chapter of this thesis, including how participants were chosen, the experiment design, data collection, and the results analysis approach.

The findings of the investigation are presented in Chapter 5, incorporating both descriptive and inferential statistics. A comprehensive discussion and interpretation of the results are provided, shedding light on their significance and implications in the context of education.

The final chapter of this thesis serves as a conclusion, encapsulating the main findings of the study and their implications for educational practices and future research endeavors. Additionally, suggestions for further improvement are offered, accompanied by an identification of the limitations inherent in the research methodology.

Chapter 2

Literature Review

In this section, this thesis outlines immersive virtual reality and its potential applications in teaching. Combining these two topics allows this research to deep-dive and analyze virtual reality's use in education and highlight some of the factors needed to design an immersive VR classroom prototype.

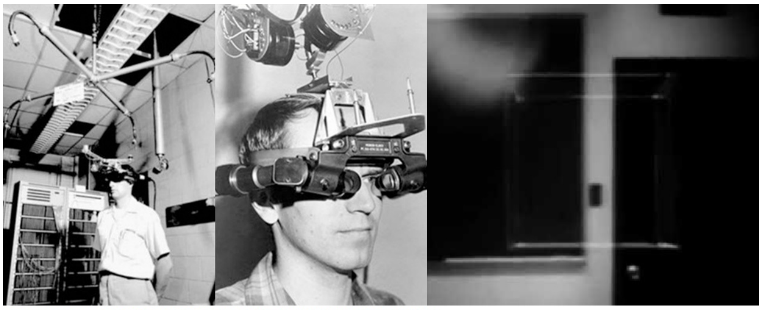
2.1 Evolution of First VR Concepts

Nowadays, Virtual Reality technologies are increasingly mentioned in public discourse, as their unique applications discover various new purposes. However, this may be surprising, but the first successful concepts of VR applications appeared in the middle of the 20th century. One such concept emerged in 1962 when Morton Heilig created a prototype known as "Sensorama" (see below Figure 1). This immersive multimodal cinema device featured a built-in display and stereo sound, offering viewers their first taste of immersive film experiences (Heilig, 1962). Despite its success, the "Sensorama" suffered from its bulky design and limited ability to provide natural and flexible mechanics, which restricted the full potential of immersion. Soon, four years later, in 1966, Ivan Sutherland developed a unique headgear, namely a head-mounted display (HMD) called "Sword of Damocles". The main mechanic of this device was to track the position of the user's head to create the illusion of a three-dimensional object. However, this technology performed the function of

Sourse: Morton Heilig and Sensorama patent (1962)
http://www.studioargento.com/immersiva/foto-immersiva6_en.html

Figure 1: "Sensorama" - an immersive, multimodal prototype

an Augmented Reality (AR) device. AR adds visions of 3D objects added to the perception of the real world (Sutherland, 1965)(see Figure 2).
Although these prototypes may be called primitive, recent developments in immersive technologies, specifically in visualization and interaction, have become increasingly popular among scientists. The value of those initial ideas and concepts laid the foundation for developing these advanced technologies. Today, VR finds



Source: The Sword of Damocles. (1965). Etsanggarp. http://etsanggarp.blogspot.com/2016/03/

Figure 2: The Sword of Damocles

applications in various sectors, showcasing its versatility and potential for future development. In healthcare, VR is employed for therapy (Pillai & Mathew, 2019), providing healthcare professionals and patients with more accurate and immersive experiences. In architecture and design, it aids in creating immersive interactive models of buildings and environments (Darwish, Kamel, & Assem, 2023). In engineering and manufacturing, VR improves the production and modeling of complex processes (Wolfartsberger, 2019; Xie et al., 2021). The sports and fitness industry utilizes VR to establish immersive training environments and enhance the rehabilitation of injured athletes (Asadzadeh, Samad-Soltani, Salahzadeh, & Rezaei-Hachesu, 2021). The military and defense sector employs VR to simulate combat situations and train soldiers in new equipment and tactics (Harris et al., 2023). Lastly, VR is extensively used in education (Lege & Bonner, 2020), which is the main focus of this thesis. Through its widespread use in these diverse fields, VR demonstrates its potential for introduction and advancement in the future.

2.2 Overview of VR Technology in Education

Despite virtual reality's growing reliability and accessibility, many still see it as a tool for entertainment. However, virtual reality has found its way into education in various ways, including virtual classrooms, simulations, and educational games. Virtual classrooms, in particular, are not a new concept and are now available in numerous versions. These classrooms offer an immersive learning experience, allowing students to engage with teachers and peers in a manner that closely mimics a traditional classroom setting. One interesting example of an application implementing virtual classrooms and environments is the "EngageVR" application by Immersive VR Education. EngageVR provides a wide range of features such as: Create and Sell pre-recorded content, Private Sessions, Create Events/Meetings/Classes, Upload 3D models, Effects Library Access, Avatar Face Generator, Desktop Streaming (Education, 2023). In addition to this application, there are many other competitive platforms that promote the use of VR for education and business in their own way. This thesis wants to consider following specific applications:

1. "Classroom Aquatic" by Sunken Places: Classroom Aquatic is a game that allows players to experience an underwater classroom in VR. The game includes educational content about marine life and oceanography (Places, 2023).

2. "Immersive Learning" by ThingLink: Immersive Learning is a platform that

allows teachers to create interactive VR lessons using 360-degree images and videos. The platform includes assessment tools and analytics to track student progress. (ThingLink, 2023).

3. "Google Expeditions" by Google: Google Expeditions is a VR platform that includes virtual field trips to locations around the world. The platform includes educational content and allows teachers to guide students together narrating the history behind these locations (Google, 2023).

These are just a few examples of the many VR classroom applications that are currently available. Each application has its own unique features and focus. Therefore, existing VR classroom applications offer many benefits, including increased engagement, interactivity, and immersion. However, they also have some limitations, such as cost, accessibility, and limited content. As the technology advances and becomes more affordable, VR classrooms have the potential to become a more widespread and effective tool for education but existing challenges must be considered to improve future VR lesson performance.

There have been studies that have reported that course development adapted to a VR classroom normally takes longer than it would take for a traditional classroom setting lesson (Scott, 2015). In her paper, Scott (2015) also highlights the importance of personalized learning that enables the flexible use of space, instructional design, and the mobilization of resources and networks to meet diverse needs not just for VR education but traditional education as well.

Following this, important benefits of using virtual worlds and gamification strategies in modern education practices was studied in Tramonti & Zheleva (2015) research. They examined the opportunities and challenges of using VR in classroom, provided opportunities for effective distance and online education, collaborative learning, and experiential activities. The article presents educational models and gamification strategies developed and tested during two successful international projects, which have shown good results in terms of innovation, engagement, and knowledge retention. The careful selection of the virtual environment, gamification strategies, and pedagogical model is crucial for building learners' confidence, encouraging positive

attitudes and behavioural changes, and supporting enriched learning experiences. Their research also concluded that many educators lack required skills and knowledge in creating classes in a virtual world (Tramonti & Zheleva, 2015).
According to a study conducted by Lavoie et al., relationships between students can be damaged after regular VR communication. Influence of the VR content can elicit negative emotional outcomes due to the increased level of absorption among users. The intense emotional experience can subsequently lead to negative rumination about the experience after it has ended, indicating a need for policymakers and VR developers to understand the emotional dangers of VR and protect consumers. The study calls for more research to understand the potential severity of negative emotional harm resulting from VR usage and explore whether VR situations that require the user to engage in morally egregious behavior intensify negative emotions even more (Lavoie et al., 2021).

2.3 Enhancing Immersion in VR

Despite the existing challenges in introducing VR into education, it is necessary to consider what positive effects VR can accomplish, as well as what factors can support this.

Motivation and Engagement

In a research paper by Loup (2016), it was demonstarted that the pervasive prototype, which included more immersive and persistent elements, led to higher levels of engagement, but there were no significant differences in learners' intrinsic, extrinsic, and autodetermined motivation levels between the two groups. An experiment was conducted comparing the impact of two different prototypes of a serious game on learners' motivation and engagement (Loup et al., 2016).
Building upon these findings, another study explored the effects of VR on engagement and motivation in educational settings (Johnson-Glenberg, 2019). It was also concluded that it improves academic performance. The article discusses the benefits of using virtual reality (VR) for educational purposes, particularly the sensation of

presence and the embodied affordances of gesture in a 3D learning space. The use of VR headsets with hand controls allows for creative, kinesthetic manipulation of content, which has been shown to have positive effects on learning process. The article recommends incorporating seamless assessment, collaboration, and principles of best practices, including the Necessary Nine, identified list of principles, when designing and implementing VR lessons for educational purposes. However, only some of these Nine Principles can be practically implemented in future research prototype, specifically, "Gestures are worth the time - they promote learning, agency, and attenuate simulator sickness"(Johnson-Glenberg, 2019, p.107). Further supporting the positive impact of VR in education, research has shown that VR not only enhances engagement and motivation but also improves academic performance. Another research highlights the importance of appropriately designed interactions in virtual worlds to enhance learner engagement. A proper orientation process, with clear instructions and encouragement to use in-world educational content, is crucial for maximizing the potential of virtual worlds. The study recommends further examination of successful orientation areas and the impact of different set-ups on interactions and engagement (Christopoulos, Conrad, & Shukla, 2018).

Drawbacks of Immersion

However, it is important to consider potential drawbacks of VR in education, as the following study has found a negative impact on educational performance. As pointed out by Huang et.al. (2019) that immersive VR learning environments may cause high cognitive load and negatively impact knowledge test performance. The study investigates the impact of immersive VR learning environments on learning outcomes from both cognitive (knowledge test performance) and affective (learning satisfaction) perspectives. The relationship among learning style, sense of presence, cognitive load, and the two learning outcomes is also discussed. The research found that different variables affect different aspects of learning outcomes, and it is important to explore their influence under the sense of presence and cognitive load. The study has practical value for educational applications, such as selecting appropriate VR devices based on teaching goals. Visual learning styles are prevalent among digital native students and education that adapts to students' comprehension styles and preferences is crucial for learning success (Huang et al., 2019).

Recent research in the field of VR learning has emphasised the benefits of using VR instruments, including voice recognition, video conference systems, and whiteboards for workflow management. These benefits include increased engagement levels, improved knowledge acquisition efficiency, enhanced accessibility, better multitasking abilities, and fostered collaboration and interaction among participants (Predescu, Caramihai, & Moisescu, 2023). However, the limitations of VR, such as dizziness, headaches, nausea, and motion sickness, need to be addressed, along with the requirement for detailed multimedia elements/materials. The study suggests that integrating classroom elements and study materials into VR applications will bridge the technology gap and provide advantages for students.

Presence and Realism

Understanding the concept of presence in VR is crucial in assessing the overall experience and its impact on users. Slater's (2018) article discusses the concept of "presence" in virtual reality and how it relates to the feeling of being in the virtual environment. The author argues that the sense of presence in VR can be influenced by various factors, including the level of immersion, sensory feedback, and user characteristics. It was also concluded that measuring presence in VR can be challenging, and that different measures, such as psychophysics-based measures, can be used to assess presence without relying solely on self-report questionnaires (Slater, 2018).

Another research studied the impact of virtual nature and presence of non-playable characters (NPC) to improve overall mood. While the focus of the research did not revolve around the subject of education, it does offer valuable insights into the potential correlations between mood and virtual reality. It involved testing a prototype called the "VR Forest Walk" to assess the impact of virtual nature and presence of NPC-dog to improve mood. feasibility and willingness of elderly individuals to use VR games. The study found that the presence of NPCs in the virtual environment had a positive impact on the participants' mood. However, there were limitations identified, such as the need for more detailed instructions, integration of interactive elements, and assistance from family members or caregivers for elderly individuals to access and use VR technology. Overall, the study concluded that VR technology can benefit elderly individuals and improve their well-being, highlighting the importance of designing and studying VR applications for this population (Graf, Liszio, & Masuch, 2020).

In the context of virtual reality exergames for older adults, research indicates that the presence of a virtual audience without feedback has no impact. However, providing reactive feedback from non-player characters (NPC) audiences improves performance, gameplay experience, perceived exertion, and subjective preference. The study suggests incorporating various cheering motions, sounds, facial expressions, cultural elements, and famous characters in future work to design VR exergames that motivate improved performance and gameplay experience for older adults (Yu et al., 2023).

But is there a limit to the naturalness of the behavior and appearance of virtual characters? There is an opinion that too high realism of virtual characters can cause very negative consequences. One research focuses on avoiding the negative effects of the "uncanny valley" effect in virtual reality. The uncanny valley is a concept that describes the unsettling feeling experienced by individuals when encountering a human-like representation that falls short of perfect realism. It highlights several factors that should be considered to prevent discomfort and maintain immersion for users. Thus, NPS that are too natural can be uncomfortable, however, one aspect described in this research is the user's familiarity with their own body, where even small deviations from realism can cause strong discomfort. High levels of realism can negatively affect the user's psychological state, leading to feelings of discomfort, disconnection, and confusion (Schwind, Wolf, & Henze, 2018).

2.4 Summary of the Literature

This analysis gives an idea of the vast possibilities of using VR technology to improve the quality of education. Furthermore, there is certainly potential, but active implementation in educational institutions around the world does not exist today.

This literature review begins by tracing the evolution of VR technology, which laid the foundation for the development of immersive technologies. The review then highlights the wide range of sectors where VR is currently being applied, including healthcare, architecture, engineering, sports, and education. The focus of the review shifts to VR technology in education, specifically virtual classrooms and the various applications available. The benefits of using VR in education are discussed, including increased engagement, interactivity, and immersion. However, limitations such as cost, accessibility, limited content and other challenges are also acknowledged. Several studies are referenced to support the positive impact of VR performance in educational settings. The review also addresses potential drawbacks of VR in education, such as high cognitive load, detrimentally impacting students' social connections, and negatively affecting knowledge test performance. The concept of presence in VR is explored, emphasizing its influence on the overall experience and the challenges of measuring it. This chapter concludes by discussing the importance of appropriately designed interactions and the need for further research to enhance learner engagement and explore the effectiveness of VR training in various domains. Overall, the literature demonstrates the potential of VR in education while acknowledging the challenges and opportunities for future development.

The main goal in developing this software is to research the role of multidimensional stimuli implementation in the VR user experience and how their impact can be understood through different measures. This project is important because it serves as a base for researchers to understand the effects of the virtual environment on the user, psychologically and educationally.

In addition, this analysis demonstrated that the development area for personalized education and immersion in virtual classrooms remains unexplored, just like the lack of research aimed at analyzing how the recognition of virtual environments affects educational success.

This literature review opens a helpful view on the main necessary characteristics for creating immersive virtual environments that should be considered when creating the thesis's future prototype. Some of the most critical dimensions include the realism of classrooms and environments, engagement, naturalness of interactions, sense of presence, and natural behavior from non-playable characters that should be taken into account in the coming design of virtual classrooms.

Chapter 3

Implementation

This section discusses the process of implementation of the VR classroom prototype. It explains why certain hardware, software, and programming choices were made and describes the process from starting up equipment to performing in the VR classroom. The implementation is based on the designs mentioned in Chapter 2.

3.1 Overview of the Prototype

This immersive prototype aims to perform different aspects of environmental recognition and analyze its impact on learning performance in a virtual environment. The prototype consists of two virtual classes, and each has a unique design and layout but is identical in its functionality and possible user actions. The first setting is a replica of an authentic university classroom, including the environment outside the virtual room. The second is a unique environment, completely novel to the participants, created from different concepts and layouts.

The prototype is a single-user application that takes the student into a virtual lecture, offering an increasingly immersive approach to watching recorded lectures from online courses. During the experiment, it was regularly mentioned that this prototype is something of an "advanced video player" where the user can watch different lecture recordings, and there is no real communication with the characters in the simulation.

The virtual environments have been carefully crafted to reflect real experiences using various immersive techniques. Specifically in this study, special attention was paid to locomotion system, spatial sound, interactive objects, lighting, non-player characters (NPCs), such as a teacher who gives a lecture and other students, and realistic illustration of slides on the screen - all this serves to create a functioning virtual reality environment. Each of the implemented features of the application will be described in the following parts of this chapter.

In addition, the prototype is equipped with a functional video player which participants can use to manipulate the lecture timeline: pause and resume. Also, the user may find that lecture slides are presented on different surfaces: blackboards and laptop screens.

Overall, this prototype represents an innovative approach to exploring the relationship between environmental perception and learning in VR. The latest immersive methods allow participants to experience a more dynamic and interactive learning environment. The results of this research are far-reaching and have the potential to help create a more effective, engaging, and personalized VR learning environment.

3.2 Technical Details and Software Used

This section provides a detailed overview of the hardware and software used to develop the immersive prototype. This section will examine the complexities of developing virtual environments, such as the design and layout of two separate virtual classrooms and the various immersive methods and development tools used. The innovative approach of this prototype could contribute to developing more efficient and engaging virtual learning settings. These recommendations may contribute to a more dynamic and interactive learning environment using virtual reality technology in the future.

3.2.1 Unity

For this research, the Unity Engine was selected as one of the top-rated and adaptable game engines for creating interactive and immersive experiences on various platforms (*Unity*, 2023). Having certain experience and background in using this software and unparalleled ability of the Unity Engine to construct visually captivating and interactive virtual reality environments were the primary reason for this decision.

The latest version of the Unity Engine, 2021.3.7f1, was used for the prototype creation, as it was the most recent and long-supporting version available during development. Moreover, since some parts of the documentation change regularly between version updates, the choice fell on the one that has the widest range of resources on documentation and tutorials.

To take the virtual reality experience to the next level, the Universal Render Pipeline (URP) within Unity was employed (Unity Technologies, 2023a). The URP is a streamlined rendering pipeline with optimized performance for VR applications. By leveraging the URP, overall performance can be optimized. The URP also permits the construction of customized shaders and effects that can further amplify the immersive quality of the virtual environment. However, no custom shaders were eventually added to the prototype.

Furthermore, the URP is perfect for VR development as it supports Single Pass Stereo rendering, reducing the load on the graphics processing unit (GPU) and improving performance in VR applications. The URP's built-in post-processing stack also enables the use of effects such as depth of field, bloom, and motion blur, which can significantly improve the virtual environment's overall visual quality and immersion. It is always recommended to use URP for VR development among most of the available resources.

3.2.2 XR Interaction Toolkit

Unity provides a free interaction package, "XR Interaction Toolkit" (Unity Technologies, 2023b). It is a tool that allows developers to simulate immersive and interactive experiences for virtual and augmented reality applications.

XR Interaction Toolkit can provide an easy solution for user interaction in virtual settings. More importantly, the software includes basic movement, grabbing, throwing, and other types of interaction. It also provides a collection of simple structures and scripts to modify, making it easy to create custom interactions.

In this project, this tool enabled most technical tasks, from obtaining the data from participant actions of the joystick to correctly displaying all movements in 3D space. Besides, setting up the correct interaction system with this package was easier. Among the interactions made possible by the XR Interaction Toolkit, participants were able to move in the virtual environment with a joystick, control objects with hand gestures, and even manipulate the lecture and NPCs animations with a virtual user interface attached to their hands. However, this package could only implement some functionalities planned for this project, but the rest was developed using custom C# scripts. More on implemented functionality see in the next section.

To summarize, the XR Interaction Toolkit was a valuable asset to this project. With this set of tools, it was far more efficient to focus on creating meaningful actions, environment design, and experiences rather than building all interactions separately.

3.2.3 C Sharp

C# (pronounced C sharp), the primary programming language used in Unity, plays a pivotal role in the development of custom scripts for extending the capabilities of the XR Interaction Toolkit (*C Sharp*, 2023). This master thesis actively used the application of C# to improve overall prototype performance. Appendix B provides a comprehensive presentation of code snippets extracted from the custom files, offering insights into the implementation details.

3.2.4 Oculus Quest 2

When implementing the prototype, it is crucial to determine a target device. The standalone VR headset, Oculus Quest 2(Meta, 2023b), was chosen as the target device to implement and test the impact of virtual environments. Due to its popularity and steady development of virtual technologies by Meta(Meta, 2023a), choosing a suitable device for future developments is essential. However, other popular VR headsets are currently available on the market, including the HTC Vive, PlaySta-

sourse: https://www.droneworld.co.za/wp-content/uploads/2022/03/Oculus-Quest-2-VR-Headset.png

Figure 3: Oculus Quest 2

tion VR, and Valve Index (Angelov, Petkov, Shipkovenski, & Kalushkov, 2020).
The main reason for using this particular device was its presence at our university; however, the use of Oculus Quest 2 in this project has several advantages. As previously stated, this device operates independently without the need for a PC connection. Besides, it meets several criteria for high-quality virtual reality immersion. As a result, one of the secondary goals of this project was to import the prototype application to the Android Oculus Quest 2 system so that the performance of the two versions of the prototype could be compared. The portability and ease of use of the Oculus Quest 2 make it a convenient and affordable research platform.
However, it is necessary to correctly determine how advantageous the headset's ability to perform separately from the computer is compared to PC operated. The performance of Unity projects on an Oculus Quest 2 connected to a PC via a patch cable or wirelessly using Oculus Air Link (over Wi-Fi) can be significantly better than running the same project on a standalone Oculus Quest 2 for several reasons. First of all, Oculus Quest 2, when connected to a PC, can use the computing power

and graphics capabilities of the computer. The PC can handle complex rendering tasks and deliver better graphics, resulting in a better visual experience with higher resolutions and smoother frame rates. Secondly, The Oculus Quest 2 itself has a powerful processor, but it may have limitations in processing power compared to a high-end gaming PC.

It is worth mentioning that the performance of a Unity project on Oculus Quest 2, whether standalone or connected to a PC, also depends entirely on the specific optimization and settings of the Unity project itself. All settings have been manually optimized to ensure the most productive and smooth experience possible. However, the difference between these two versions may be hardly noticeable in the Figure 4 below. Since various free 3D models with different file sizes were utilized in this

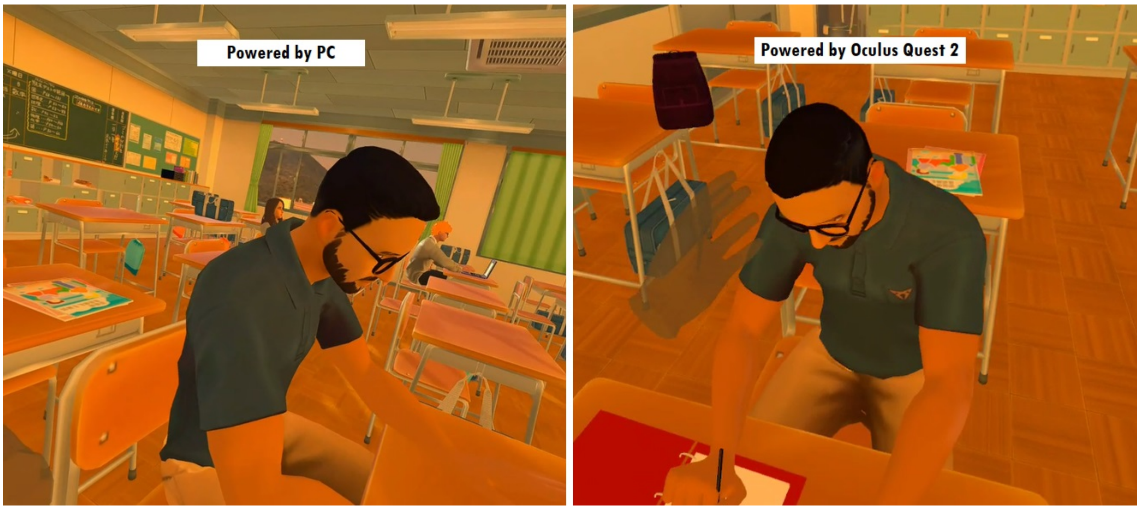


Figure 4: PC vs Oculus Quest 2

project, each model may have a different weight. Therefore, evaluating the relatively poor-quality processing of the same project elements is not beneficial.

To sum it up, Oculus Quest 2 proved to be a reliable and efficient device for the implementation and testing of such educational technology.

3.2.5 GitHub

The VR classroom prototype development process has been an arduous journey; however, accompanied by GitHub as a trusted companion using its powerful version control system. At this point, two machines with different hardware capabilities were used: one at home with a modest graphics card and the other in a university lab with advanced graphics cards and higher processing power.

GitHub is a web-based hosting service that provides a platform for version control, collaborative software development, and source code management (*GitHub*, 2023). It allows developers to store, manage, and share their code repositories, collaborate with team members, track changes made to code, and contribute to open-source projects. GitHub has organized the correct coordination between these two machines, smoothing the development process. Changes made to the project on one machine were accordingly merged on a main server, which made it easy to track changes and ensure that project files were backed up reliably. Therefore, GitHub is a unique tool for such projects. Additionally, this project repository of the prototype can be accessed with the link in Appendix B.

3.2.6 Unity's Additional Plugins

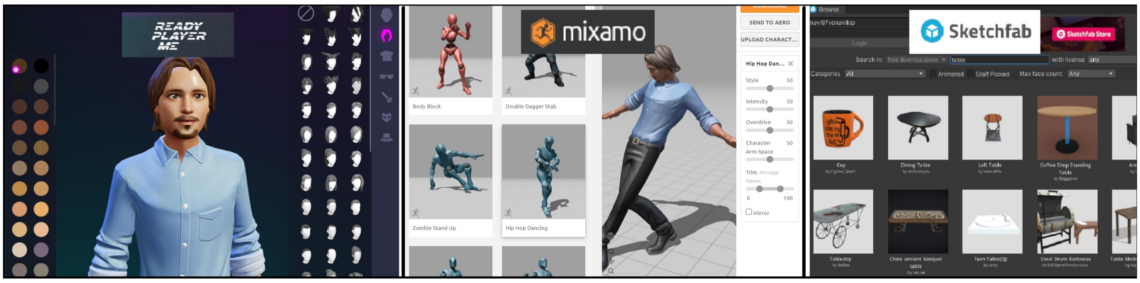


Figure 5: Used plugins (left to right): Ready Player Me, Mixamo, Sketchfab

In this development process, three standout tools take the attention: **Sketchfab**, **Mixamo**, and **Ready Player Me**. These plugins provide unparalleled capabilities for creating realistic characters and animations, elevating the quality and realism of simulations to higher levels.(*Sketchfab*, 2023; *Mixamo*, 2023; *Ready Player Me*, 2023).

Let's start with the Sketchfab plugin, which unlocks access to 3D models within Unity. With Sketchfab, developers can effortlessly import top-quality 3D models into their scenes, saving time and effort in crafting assets from scratch. The plugin offers a rich repository of diverse models, including characters, objects, and environments. These assets bring a new level of complexity to the virtual world.

Next up is Mixamo, an animation powerhouse that empowers developers to breathe life into characters with a stunning array of pre-made and custom animations. Mixamo's vast library of animations covers the entire spectrum, from subtle gestures to intricate actions. As a result, providing these characters with actions to enhance the simulations' overall immersion and engagement.

And then there's Ready Player Me, a unique plugin that lets you generate customizable 3D avatars. Powered by cutting-edge AI technology, Ready Player Me lets to create character models with various styles. With just a few clicks, developers and users can customize facial features, hairstyles, clothing, and more, crafting unique and dynamic NPCs. Integrating such a tool into this application can personalize and simplify avatar creation. When all avatars are created, Mixamo can further animate these characters, completely integrating them into the virtual simulation.

The importance of NPCs and realistic animations in simulations cannot be overstated. NPCs are the backbone of immersive experiences, providing a sense of presence and interactivity that captivates users. Realistic animations are the "soul" of virtual characters, conveying emotions, actions, and interactions with authenticity. Combining Sketchfab, Mixamo, and Ready Player Me in Unity delivered a helpful arsenal of tools for combining characters and animations.

3.2.7 Prototype Features

The following list shows the features that were successfully implemented in the prototype:

- **Video Player:** With the help of Unity's built-in feature, users play videos within the virtual reality environment, providing a multimedia experience. Video is displayed on laptops and desks (Figure 6).

- **Wrist UI Menu:** A simple virtual tablet was created to provide users with a simple way of performing different actions: standing up and sitting back down, changing seats, and manipulating the lecture settings (see Figure 7).

Figure 6: Prototype's Video Player

- **Seat Selection:** This feature was implemented with a custom C# script that enables users to choose and occupy virtual seats within the virtual environment, providing a sense of presence and mobility.

- **Sound volume control:** A feature that allows users to adjust the volume of sounds within the virtual environment, providing control over the audio experience and ensuring a comfortable listening experience. A custom C# script was required to connect user's actions and video settings.

- **Control timeline of the presentation:** This feature was achieved by creating a custom C# script that pauses and resumes the application timeline, meaning it stops both lecture and non-playable characters from operating. That allows users to control the timeline of a presentation, providing interactive control over the content. It also creates a science fiction effect of a time pause, during which students can inspect the "frozen" reality.

- **Locomotion System:** For this prototype, a teleportation type of locomotion was chosen as it is known for having less motion sickness among participants. With this feature, users can navigate and move within the virtual environment, providing a means of exploration (see Figure 8).

- **Camera Reset Button:** This might be the only feature that also has a debugging purpose. During the implementation and testing phase, it was discovered that head position in VR depends on the device's current space tracking. In order to take control of the correct positioning of the head at

Figure 7: Prototype's Wrist Menu

Figure 8: Prototype's Teleportation feature

the start of each lesson, a custom C# script was created. This allows users to reset the camera position and orientation to a default position, providing a way to reset the user's view in case of incorrect positioning of the Oculus Device in virtual 3D space.

- **Spatial Audio:** This feature provides realistic audio cues based on the user's position and orientation within the virtual environment, enhancing the immersion and sense of presence.

- **Multiple NPCs:** A feature that includes multiple non-player characters

(NPCs) within the virtual environment, providing interactive elements and potential interactions with virtual characters.

Figure 9: Prototype's NPCs

- **Lighting:** With this built-in feature and proper settings, VR classroom prototype tries to provide correct lighting within the virtual environment, supplying realistic visual quality.
- **Controller Bindings:** Several controller actions were manually implemented in order to complete multiple interactions, such as Menu Toggle, Teleportation, and Grabbing features.

3.3 Environmental Design and User Experience

The design of the three virtual reality environments in this study was a significant aspect of the research, aimed at investigating the impact of environmental recognition on learning performance in immersive VR. The first scene, referred to as the "real-life replica", was specifically crafted to replicate a university classroom and campus. This involved a multi-step process, including capturing photos of an actual classroom and its surroundings from multiple angles, which served as references for creating the virtual copy.

RenderDoc and Google Earth were used to generate a detailed 3D model of the campus and main building (*RenderDoc*, 2019; Google, 2001). Still, the textures from Google Earth were of insufficient quality and unsuitable for immediate use in the virtual environment. As a result, the interior and exterior of the main building were created from scratch to ensure a high level of realism (see Figure below). This

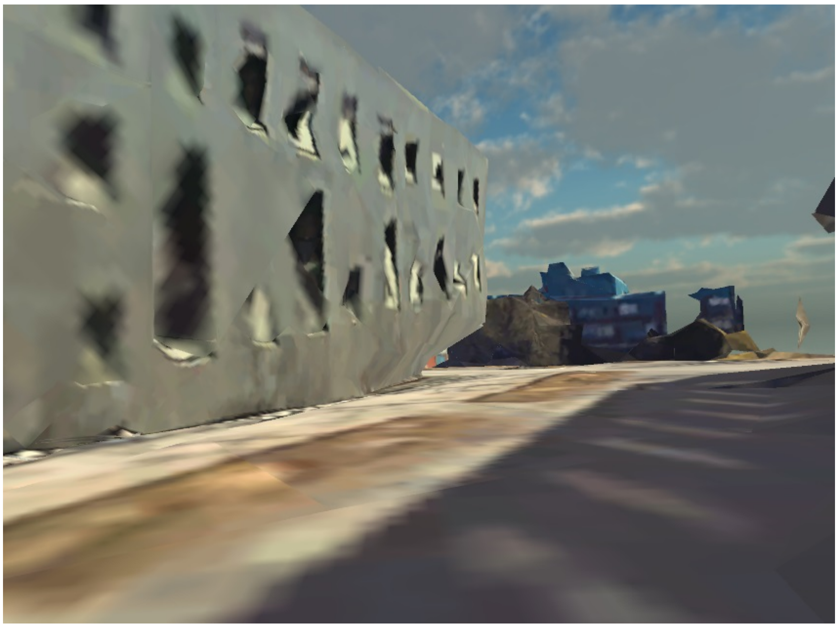


Figure 10: Extracted Google Earth model quality

task involved integrating Sketchfab models and applying diverse textures to basic 3D models from Unity, such as the floors, walls, and backboard. Attention was also paid to secondary details outside the classroom window, including roads, ladders, parking lots, trees, cars, people, and walls, to create a sense of authenticity and immersion. The skybox was replaced with clouds, and ambient sounds, specifically "pink noise", were applied to the opened window to mimic the outside world, enhancing the location's impact. Pink noise has a steady sound that is even and flat. Once the design of the first room was considered complete, the focus shifted to the user experience and in-game mechanics, which is described in the "Prototype Features" section.

Next, the second virtual classroom, introduced as the novel environment, was developed with a distinctive and unfamiliar setting in contrast to the real-life replica. A captivating Japanese school style and design were chosen for this classroom. A pre-existing asset of a Japanese classroom from the Unity Asset Store was integrated as a starting point (Unity Technologies, n.d.). Additional minor models were added to the environment. Since the design of the second classroom used several assets and functional elements from the first environment, the process was speed-up significantly.

In addition to the classrooms, a third environment was designed as a control condi-

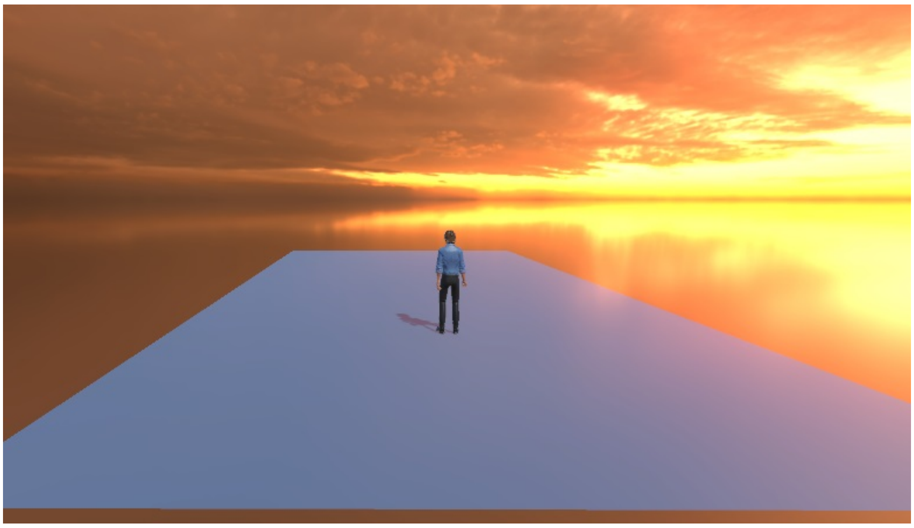


Figure 11: Testing environment

tion. This minimalist environment consisted of an empty room with a simple floor, a skybox for the background, and a user for testing purposes. This room served as the testing ground for testing crucial factors such as the teleportation feature, opening and closing of the Wrist Menu, sound volume, and manual head turning with a joystick. During the experiment, participants were instructed to select the virtual classroom they were assigned to using the Wrist UI buttons in the VR environment. In conclusion, this study's detailed design of the three VR environments involved creative effort and cutting-edge tools. The attention to detail, realism, and immersion in each domain was carefully considered to provide a compelling and controlled experience for the participants, producing findings on the impact of VR research.

3.4 Challenges in the Development Process

Integration and Compatibility between Mixamo and Ready Player Me

One challenge encountered during the implementation of the project was the incompatibility between Mixamo and Ready Player Me in processing avatar files. The .glb files generated by Ready Player Me were not processed correctly by Mixamo, resulting in avatars appearing completely white without textures and with sometimes distorted and incorrectly positioned bones as depicted on Figure below. To resolve

Figure 12: Mixamo texture processing issue

this issue, Blender version 2.9 was used, as it was capable of baking the model with textures in a manner that Mixamo recognized different textures correctly.
The incompatibility between Mixamo and Ready Player Me posed a limitation in utilizing the mouth sync feature provided by the Ready Player Me plugin in Unity, as the avatars had to be imported in a different format due to processing issues. This necessitated a sacrifice of the mouth sync feature due to time constraints.
To overcome this issue for future researchers, it is recommended to thoroughly test the compatibility between different tools and plugins during the avatar creation process. Ensuring that the chosen tools are compatible with each other can help

avoid unexpected issues and save time in troubleshooting and fixing such incompatibilities. Additionally, staying updated with the latest versions of the software and plugins used in the project may provide solutions to known issues and improve compatibility.

Realism and Recognition

Achieving a high level of realism and recognition in the virtual replica of the real-life environment was a significant challenge. Ensuring that the virtual environment closely resembled the real university area required careful attention to details such as textures, lighting, and object placement. Overcoming limitations in the quality of textures extracted from Google Earth was also a challenge.

Time and Resource Constraints

Time and resource constraints were also a challenge during the implementation process. Recreating the virtual environments from real-life photos and integrating them into Unity required considerable time and effort. Additionally, ensuring that the virtual environments were optimized for performance and compatible with the VR device took some research.

User Experience and Functionality

Ensuring a smooth and immersive user experience was another challenge. Implementing user interactions, such as teleportation, opening and closing the Wrist Menu, and controlling sound volume, requiring careful attention to functionality and usability. Ensuring that the virtual environments provided a seamless and intuitive experience for the participants was crucial to the success of the experiment.

Chapter 4

Experimental Design

This chapter presents an elaborate understanding of the procedure followed for experiment design, data collection, and analysis. The study was conducted as a cross-subject design experiment with two prototype classroom options. The basis of the study design was that in order to be able to measure the impact of the virtual environment, it is necessary to observe the impact of changes in the results on knowledge of the chosen topic before and after the virtual experience. In addition, this study design provides insight into how the use of a virtual classroom affects various characteristics of VR immersiveness.

4.1 Participants

A total of 10 individuals - six women and four men - were recruited to participate in the experiment. All of them were students in bachelor's and master's programs at the Cognitive Science faculty of the University of Osnabruck. All of them were above 18 years of age. It was also ensured that they had normal vision and hearing. Participants had no prior experience with the virtual lecture topic.

Participants were separated into two groups based on their recognition of photos of an actual university classroom. Those who correctly named the location of a classroom and confirmed that they had been there at least three times were assigned to Group 2 and placed in the familiar virtual environment. Participants who did

not recognize the location of the classroom were assigned to Group 1.
All participants gave written consent prior to participating and were informed of the purpose of the study after the completion of the experiment.

4.2 Virtual Lecture

The lecture topic "10 Basic Principles of Economics" was chosen for the experiment because the participants had no professional or educational background in economics. It aimed to introduce them to the fundamental principles of economics that serve as the basis for most economic theories for beginners. By covering these principles, the lecture intended to provide participants with a foundational understanding of economic concepts.
The economics lecture, given by Birmingham, R. J. (2021) was selected as the original version of the future virtual lecture (Birmingham, 2021). To prepare the lecture for the experiment, several steps were taken. First, the original video lasted 30 minutes, but to fit the experiment's constraints, the lecture script was condensed to 17 minutes. This involved selecting only the main concepts and including only one example for each principle, ensuring the key ideas were conveyed within the time limit. Then, the lecture was recorded with minor speech mistakes and pauses to make it sound more authentic and natural, as the experimenter of this research was neither an actual teacher nor a lecturer. This approach aimed to create a realistic lecture experience for the participants. Finally, a 15 multiple-choice questions knowledge assessment was created based on the shortened and modified script.

4.3 Measures and Data Collection

The entire experiment took place in a closed room, where the subject did not need to move widely and was almost completely static on a chair near the table space. The set-up of the experimental room is shown in Figure below.
If we do not take into account the standard health survey and division into groups, then in order to obtain all the necessary data for analysis, the experiment contained the following dependent variables: pre-and post-testing, Likert scale, and interview.

Figure 13: Experiment set-up

4.3.1 Pre- and Post- Knowledge Assessment

To answer the first research question ("How does the virtual environment affect participants' understanding of the learning material?"), a t-test was conducted to compare the average scores of the two groups on knowledge assessment before and after the test. The significant difference between the two groups suggests that the virtual environment does have a certain influence on participants' understanding of the learning material.

Thus, each assessment consists of 15 multiple-choice questions about the "10 Basic Principles of Economics."

A very important detail is that in pretesting, each question has a fifth "I don't know" response option to provide clearer results and minimize the possibility of guessing the correct answer. Participants were asked to pay particular attention to this option and try to weigh their decisions correctly.

"The 10 Basic Principles of Economics" was the topic of the lecture, which was presented to each participant later in the respective virtual classroom with a simulated lecture design. The post-test contained exactly the same questions but in a different order and without the "I don't know" option. For a full list of questions used in Knowledge Assessment, see Appendix A.

4.3.2 Likert Scale

To answer the second research question ("How do participants perceive the virtual environment in terms of its realism, immersion, and interaction with educational content?"). This survey questions on the Likert scale are aimed to assess various aspects of participants' perception of the virtual reality environment and their involvement in educational content. Questions were distributed among following dimensions:

- realism;
- immersion;
- interaction;
- ease of use;
- comfort;
- future accessibility;
- naturalness of interaction;
- and effectiveness of the virtual environment in facilitating learning.

The Likert scale was chosen for this study because it provides the collection of quantitative data that can be analyzed using statistical methods. It is a simple and convenient format for participants to express their opinions. The use of the Likert scale provides a standardized method for measuring participants' attitudes and perceptions and facilitates comparison and analysis of results. The survey conducted not only provides an opportunity for participants to express their perception of different immersive domains but also explains the virtual environment's strengths and weaknesses within the research prototype. The feedback garnered from this survey serves as a valuable resource for optimizing and enhancing the virtual learning experience in the future.

1. How realistic did you find the virtual reality environment?

- Not at all realistic
- Slightly realistic
- Moderately realistic
- Very realistic
- Extremely realistic

2. How immersive did you find the virtual reality environment?

   - Not at all immersive
   - Slightly immersive
   - Moderately immersive
   - Very immersive
   - Extremely immersive

3. How engaged did you feel with the educational content in the virtual reality environment?

   - Not at all engaged
   - Slightly engaged
   - Moderately engaged
   - Very engaged
   - Extremely engaged

4. How easy was it for you to interact with the virtual reality environment?

   - Not at all easy
   - Slightly easy
   - Moderately easy
   - Very easy
   - Extremely easy

5. How likely are you to use virtual reality technology for educational purposes in the future?
    - Not at all likely
    - Slightly likely
    - Moderately likely
    - Very likely
    - Extremely likely
6. How comfortable are you with virtual reality technology?
    - Not at all comfortable
    - Slightly comfortable
    - Moderately comfortable
    - Very comfortable
    - Extremely comfortable
7. How natural was the interaction with the virtual reality environment?
    - Not at all natural
    - Slightly natural
    - Moderately natural
    - Very natural
    - Extremely natural
8. How well did the virtual reality environment facilitate your understanding of the educational content?
    - Not at all likely
    - Slightly likely
    - Moderately likely
    - Very likely
    - Extremely likely

4.3.3 Interview

Finally, to answer the third research question ("What are the participants' subjective experiences and feedback on the VR classroom?"). The interview consisted of nine open-ended questions. The interviews were recorded to make it more natural and relaxing to participants and later transcribed and analyzed. Their answers can help to specify the overall feedback from the experiment and see if there are any correlations between both groups of participants.

Q1. How did it feel to be in the virtual classroom?

The aim of this question is to get the participants to describe their first impression and their overall experience in the virtual classroom. The data collected from this question is the participant's overall impression of the virtual classroom and whether they felt comfortable or not. The question also targeted the participant's general mood during the experiment and how it had influenced their experience.

Q2. What were your initial thoughts and expectations about the VR environment before you began the experiment? How did these change as you went through the experience?

The aim of this question is to understand the participant's expectations and thoughts before entering the virtual classroom and how they changed during the experiment. The data collected from this question tries to investigate whether the participant had any preconceived notions about the VR environment and how their experience altered or confirmed their initial thoughts. The question also targeted the participant's level of anticipation and how it had influenced their perception of the environment.

Q3. How did you find the interactions and presence of the teacher and other students in the virtual classroom? Were they realistic and engaging?

The aim of this question is to evaluate the overall engagement and realism of the teacher and other students in the virtual classroom. Specifically, the data collected from this question represents the participant's perception of the actions and presence of the teacher and other students and whether it enhanced or detracted from the learning experience. The question also targeted the participant's level of comfort in interacting with virtual characters.

Q4. How did the VR environment impact your engagement and motivation to learn the educational content?

The aim of this question is to examine the impact of the VR environment on the participant's engagement and motivation to learn the educational content. The data collected from this question was whether the immersive environment positively impacted the participant's engagement with the content and whether it increased their motivation to learn. The question also targeted the participant's level of interest in the topic being taught.

Q5. Was there anything that the VR environment allowed you to do that would be difficult or impossible in a traditional classroom setting?

The aim of this question was to identify the unique actions or effects of the VR environment that might not have been possible in a traditional/real classroom. The data collected from this question was whether the VR environment allowed the participant to do anything that they would not have been able to do in a traditional classroom setting. The question also targeted the participant's level of excitement or curiosity about the abilities of the VR environment.

Q6. Were there any specific aspects of the VR environment that you found particularly helpful or unhelpful for learning the educational content?

The aim of this question was to understand which aspects of the VR environment were helpful or unhelpful for learning the educational content. The data collected from this question was the participant's perception of specific aspects of the VR environment, such as the spatial audio or teacher animations, and whether they facilitated or hindered their learning experience. The question also targeted the participant's preferences for specific aspects of the VR environment.

Q7. What feedback would you give to improve the VR environment to enhance the learning experience?

The aim of this question was to gather feedback on how to improve the VR environment to enhance the learning experience. The data collected from this question was the participant's suggestions for improving the VR environment, such as adding more interactive elements or improving the graphics. The question also targeted the participant's level of satisfaction with the VR environment.

Q8. How do you see the use of VR technology in education evolving in the future?

The aim of this question was to gather the participant's opinions on the potential evolution of VR technology in education. The data collected from this question was the participant's perception of how VR technology could be used in the future for educational purposes. The question also targeted the participant's level of interest or excitement about the potential of VR technology.

Q9. Are there any specific features that you would like to see in a VR classroom?

The aim of this question was to identify any specific features that the participant would have liked to see in a VR classroom. The data collected from this question was the participant's preferences of a VR classroom. The question also targeted the participant's level of imagination and creativity in envisioning potential missing features.

4.4 Experiment Flow

The whole experiment lasted no more than 60 minutes and was carried out in laboratory conditions. As a first step, the participant was asked to complete a screening form to clarify if they had any medical conditions or other factors that might affect their participation, such as headaches. The participant was introduced to the secondary purpose of the experiment, namely, to test the effectiveness of viewing a lecture in a virtual classroom. However, the influence of the environment was not mentioned as a central factor in this study.

After the screening form, the participant was introduced to a couple of photographs of one of the university's classrooms and asked if they recognized it. If the participants recognized the class, they were placed in a recreated version of that class, and if not, they were placed in a Japanese-style class. The number of visits to this classroom was also a mandatory factor in the group assignment.

Participants then completed the first Knowledge Assessment questionnaire, which consisted of 15 questions with five response options about the 10 Fundamental Principles of Economics, with a fifth optional "I don't know" choice. The experimenter pointed out the importance of clear decisions.

After completing the first questionnaire, the participants were introduced to the Oculus Quest 2 and shown how to use it. They were also instructed on how to fit the headset properly. Then the participants were placed at a table with free space around them so nothing would prevent them from moving.

Before starting the virtual lecture simulation, participants were placed in a "test environment" to familiarize themselves with the virtual reality environment. One readiness is confirmed, participant selects the assigned group number on the virtual wrist menu attached to the left hand. After that, any communication between the participant and the researcher is limited. In the event of technical failures, the application could be paused for troubleshooting.

Immediately after completing the simulated virtual lecture, the participant completed a second "Knowledge Assessment Part 2" questionnaire, which presented the same 15 questions as the first questionnaire, but without the "I don't know" option. Following this, participants were asked to complete a questionnaire on a Likert scale to rate their perception of the virtual reality environment. Finally, the last stage of the study is a nine-question interview to gather their feedback and impressions of the virtual reality experience. The interviews were tape-recorded with the permission of the participants.

Chapter 5

Results

Chapter 4 describes the process of conducting an experiment on a prototype VR Classroom based on research questions and how important data can be collected. Therefore, Chapter 5 describes the results of collecting, analyzing, and reporting data from the case study.

5.1 Pre- and Post-Knowledge Assessment Results

As was previously mentioned, Group 1 was placed in a novel environment (NE) while Group 2 was in a familiar one (FE).

Pre-testing has shown that participants from Group 1 ($n = 5$) have a Mean Score (M) of 7.6 and a Standard Deviation (SD) of 1.67. Besides, Group 2 ($n = 5$) has demonstrated a slightly higher score of $M = 8.2$ and $SD = 1.30$. However, a relatively high SD for both groups has proved that there was also a fair amount of variability between scores in each group. Thus, we can assume that both groups have similarly distributed knowledge on the topic.

The post-test results for Group 1 participants ranged from 12 to 14, with $M = 12.6$ and $SD = 0.89$. The post-test results for Group 2 participants ranged from 14 to 15, with $M = 14.4$ and $SD = 0.55$. An unpaired two-sample t-test was performed to determine if there was a significant difference in post-test scores among groups from different virtual environments. This analysis will help answer the question

Table 1: Pre-Knowledge Assessment Results

Group 1 (NE)	
Participant	Score
1	5/15
2	9/15
3	8/15
4	9/15
5	7/15
Average	7.6

Group 2 (FE)	
Participant	Score
1	8/15
2	7/15
3	7/15
4	10/15
5	9/15
Average	8.2

Table 2: Post-Knowledge Assessment Results

Group 1 (NE)	
Participant	Score
1	12/15
2	12/15
3	13/15
4	14/15
5	12/15
Average	12.6

Group 2 (FE)	
Participant	Score
1	15/15
2	14/15
3	15/15
4	14/15
5	14/15
Average	14.4

of whether there is a significant difference in the understanding of the educational material and the influence of a particular classroom on this. The t-test results gave a t-score of 3.8471.

$$SE = sqrt[(0.89^2/5) + (0.55^2/5)] = 0.4679$$

and standard error of difference 0.4679 and two-sided p-value 0.004898. With a 95% confidence interval, the mean difference between the two groups was -1.8, with a confidence interval of -2.877 to -0.721. The critical value of t is approximately 2.306.

These results indicate that the participants in the second group who performed in a familiar environment reported significantly better results in the post-test. The findings indicate that people comprehend educational content more effectively when they are in a familiar setting, such as a recreation of their school/university/college classroom. The results of this analysis also imply that using virtual reality technology to simulate educational settings can positively affect student learning and lead to better academic outcomes.

Calculating the improvement in participants' knowledge by comparing their progress between pre-test and post-test results is also possible, which might demonstrate their personal improvement. To do this, take a look at the improvement of each student in both groups and find the average percentage of progress using the following formula:

$$PercentageChange = ((PostScore - PreScore)/PreScore)x100$$

This is very important to properly normalize the results by dividing the difference by the pre-test score. It allows us to compare the percentage change of students who started at different levels of performance on the assessment. In order to make fair comparisons between students who began with varying levels of knowledge, normalization is necessary. The results of these calculations are shown in the Table below. Based on these calculations, it is clear that the mean percentage change of

Table 3: Pre- and Post-Knowledge Assessment Individual progress

Group 1 (NE)

Participant	Pre-test Score	Post-test Score	%, progress
1	5/15	12/15	140%
2	9/15	12/15	33.33%
3	8/15	13/15	62.5%
4	9/15	14/15	55.55%
5	7/15	12/15	71.42%
Average	7.6	12.6	72.56%

Group 2 (FE)

Participant	Pre-test Score	Post-test Score	%, progress
1	8/15	15/15	87.5%
2	7/15	14/15	100%
3	7/15	15/15	114.3%
4	10/15	14/15	40%
5	9/15	14/15	55.55%
Average	8.2	14.4	79.47%

the Group 2 participants is slightly higher ($M = 79.47\%$) than the mean percentage of Group 1 participants ($M = 72.56\%$). However, the standard deviation of both groups (*SD1* = 40.24; *SD2* = 30.94) is too high to draw conclusions from percentage change alone, so t-score results from post-test results are considered more accurate.

5.2 Likert Scale Survey Results

The results for each question in the VR Classroom Likert Survey are as follows:

- **Question 1: "How realistic did you find the virtual reality environment?"**

Table 4: Likert Scale Results Results, Question 1

Group 1 (NE)		Group 2 (FE)	
Participant	Score	Participant	Score
1	3	1	3
2	2	2	4
3	2	3	3
4	4	4	3
5	2	5	4
Average	2.6	Average	3.4

Based on participants' responses, their scores in Group 1 ($M = 2.6$, $SD = 0.89$) and Group 2 ($M = 3.4$, $SD = 0.55$) were compared using the two-tailed Mann-Whitney U-test. The U-value is 5.5, with the critical U-value at $p < 0.05$ being 2, and the z-score being -1.35781 at a p-value of 0.17384. These results indicate that there is no statistically significant difference in the realism scores of the VR environment between the two groups at the $p < 0.05$ level. It is important to note that while there was no significant difference, the mean score of 2.6 for group 1 suggests that participants in this group rated the VR environment as less realistic than those in group 2 ($M = 3.4$). Besides, the relatively low standard deviation of 0.89 and 0.55 for both groups, respectively, supports this notion. This suggests that there was relatively little variation in scores within this group. Therefore, the results of the first question indicate that participants in Group 1 perceived the virtual reality environment as less realistic than participants in Group 2. However, the lack of statistical significance means that it is important to be careful when interpreting these results and conducting further analysis.

- **Question 2: "How immersive did you find the virtual reality environment?"**

Table 5: Likert Scale Results, Question 2

Group 1 (NE)		Group 2 (FE)	
Participant	Score	Participant	Score
1	5	1	3
2	3	2	4
3	3	3	5
4	4	4	3
5	2	5	5
Average	3.4	Average	4

Based on participants' responses, their scores in Group 1 ($M = 3.4$, $SD = 1.14$) and Group 2 ($M = 4$, $SD = 1$) were compared using the two-tailed Mann-Whitney U-test. The U-value is 8.5, with the critical U value at $p < 0.05$ being 2, and the z-score being -0.73113 at a p-value of 0.4654. These results indicate that there is no statistically significant difference in the immersion of the VR environment between the two groups at the $p < 0.05$ level. It is important to note that while there was no significant difference, the mean score of 4 for Group 2 suggests that participants in this group rated the VR environment as more immersive than those in group 1 ($M = 3.4$). Besides, the relatively low standard deviation of 1.14 and 1 for both groups, respectively, supports this notion. This means that there was relatively little variation in scores within this group. However, the lack of statistical significance means that it is important to be careful when interpreting these results and conducting further analysis.

- **Question 3: "How engaged did you feel with the educational content in the virtual reality environment?"**

Based on participants' responses, their scores in Group 1 ($M = 3.6$, $SD =$

Table 6: Likert Scale Results, Question 3

Group 1 (NE)		Group 2 (FE)	
Participant	Score	Participant	Score
1	4	1	3
2	4	2	5
3	1	3	4
4	4	4	2
5	5	5	4
Average	3.6	Average	3.6

1.52) and Group 2 (M = 3.6, SD = 1.14) were compared using the two-tailed Mann-Whitney U-test. The U-value is 8.5, with the critical U-value at $p < 0.05$ being 2, and the z-score being -0.73113 at a p-value of 0.4654. These results indicate that there is no statistically significant difference in the immersion of the VR environment between the two groups at the $p < 0.05$ level. It is important to note that while there was no significant difference, the mean score of 3.6 for both groups suggest that participants were similarly well engaged with the educational content. Besides, the relatively low standard deviation of 1.14 and 1 for both groups, meaning that there was relatively little variation in scores within each group. However, the lack of statistical significance means that it is important to be careful when interpreting these results and conducting further analysis.

- **Question 4: "How easy was it for you to interact with the virtual reality environment?"**

Table 7: Likert Scale Results, Question 4

Group 1 (NE)		Group 2 (FE)	
Participant	Score	Participant	Score
1	5	1	3
2	3	2	5
3	5	3	5
4	3	4	3
5	3	5	3
Average	3.8	Average	3.8

Based on participants' responses, their scores in Group 1 ($M = 3.8$, $SD = 1.10$) and Group 2 ($M = 3.8$, $SD = 1.10$) are exact and were compared using the two-tailed Mann-Whitney U-test. The U-value is 12.5, with the critical U- value at $p < 0.05$ being 2, and the z-score being 0.10445 at a p-value of 0.92034. Apparently, these results indicate that there is no statistically significant difference in the immersion of the VR environment between the two groups at the $p < 0.05$ level and no significant difference in the mean score of 3.8 for Group 1 and Group 2 as well. Thus, it suggests that participants in both groups equally rated the VR interaction as somewhat moderate and very easy. Besides, the relatively low standard deviation of 1.10 and 1 for both groups, respectively, supports this notion.

- **Question 5: "How likely are you to use virtual reality technology for educational purposes in the future?"**

Table 8: Likert Scale Results, Question 5

Group 1 (NE)		Group 2 (FE)	
Participant	Score	Participant	Score
1	5	1	2
2	4	2	3
3	2	3	5
4	2	4	2
5	3	5	5
Average	3.2	Average	3.4

Based on participants' responses, their scores in Group 1 ($M = 3.2$, $SD = 1.30$) and Group 2 ($M = 3.4$, $SD = 1.52$) were compared using the two-tailed Mann-Whitney U-test. The U-value is 11.5, with the critical U-value at $p < 0.05$ being 2, and the z-score being -0.10445 at a p-value of 0.92034. These results indicate that there is no statistically significant difference in the likelyness of the VR environment between the two groups at the $p < 0.05$ level. It is important to note that while there was no significant difference, the mean score of 3.4 for Group 2 suggests that participants in this group rated slightly higher that they are moderately likely to use virtual reality technology for educational purposes in the future than participants in group

1 (M = 3.2). However, the relatively high standard deviation of 1.30 and 1.52 for both groups, respectively, indicates that there was also a fair amount of variability between answers in each group. Nonetheless, the lack of statistical significance means that it is important to be careful when interpreting these results and conducting further analysis.

- **Question 6: "How comfortable are you with virtual reality technology?"**

Table 9: Likert Scale Results, Question 6

Group 1 (NE)		Group 2 (FE)	
Participant	Score	Participant	Score
1	5	1	3
2	5	2	5
3	5	3	5
4	5	4	3
5	4	5	4
Average	4.8	Average	4

Based on participants' responses, their scores in Group 1 ($M = 4.8$, $SD = 0.45$ and Group 2 ($M = 4$, $SD = 1$) were compared using the two-tailed Mann-Whitney U-test. The U-value is 6.5, with the critical U-value at $p < 0.05$ being 2, and the z-score being 1.14891 at a p-value of 0.25014. These results indicate that there is no statistically significant difference in the comfort of the VR environment between the two groups at the $p < 0.05$ level. It is important to note that while there was no significant difference, the mean score of 4 for Group 2 suggests that participants in this group rated comfort lower than Group 1 (M = 4.8). It means that familiar environment might have a slight influence on the level of comfort. Besides, the relatively low standard deviation of 0.45 (Group 1) and 1 (Group 2) indicates that there was there was relatively little variability in the between answers in each group. Together, the results for the question suggest that participants in both groups are comfortable with virtual reality technology, with participants in group 1 being more comfortable on average. Nonetheless, the lack of statistical significance means that it is important to be careful when interpreting these results and conducting further analysis.

- **Question 7: "How natural was the interaction with the virtual reality environment?"**

Table 10: Likert Scale Results, Question 7

Group 1 (NE)		Group 2 (FE)	
Participant	Score	Participant	Score
1	2	1	2
2	2	2	4
3	4	3	2
4	4	4	3
5	4	5	3
Average	3.2	Average	2.8

Based on participants' responses, their scores in Group 1 ($M = 3.2$, $SD = 1.10$) and Group 2 ($M = 2.8$, $SD = 0.84$) were compared using the two-tailed Mann-Whitney U-test. The U-value is 9.5, with the critical U-value at $p < 0.05$ being 2, and the z-score being 0.52223 at a p-value of 0.60306. These results indicate that there is no statistically significant difference in the naturalness of interactions scores of the VR environment between the two groups at the $p < 0.05$ level. It is important to note that while there was no significant difference, the mean score of 3.2 for group 1 suggests that participants in this group rated the VR environment to be more natural than those in group 2 ($M = 2.8$). Besides, the relatively low standard deviation of 1.10 and 0.84 for both groups, respectively, supports this notion, and suggests that there was relatively little variation in scores within this group. Therefore, the results of the this question indicate that participants in Group 1 perceived the interaction with virtual reality environment as more natural than participants in Group 2. However, the lack of statistical significance means that it is important to be careful when interpreting these results and conducting further analysis.

- **Question 8: "How well did the virtual reality environment facilitate your understanding of the educational content?"**

Table 11: Likert Scale Results, Question 8

Group 1 (NE)		Group 2 (FE)	
Participant	Score	Participant	Score
1	5	1	3
2	4	2	3
3	2	3	5
4	4	4	4
5	4	5	4
Average	3.8	Average	3.8

Based on participants' responses, their scores in Group 1 ($M = 3.8$, $SD = 1.10$) and Group 2 ($M = 3.8$, $SD = 0.84$) were compared using the two-tailed Mann-Whitney U-test. The U-value is 11.5, with the critical U-value at $p < 0.05$ being 2, and the z-score being 0.10445 at a p-value of 0.92034. These results indicate that there is no statistically significant difference in the naturalness of interactions scores of the VR environment between the two groups at the $p < 0.05$ level. It is important to note that while there was no significant difference, the mean score of 3.8 for group 1 and the same mean score for Group 2 suggests that both groups rated the virtual reality environment as similarly effective in facilitating their understanding of the educational content. Besides, the relatively low standard deviation of 1.10 and 0.84 for both groups, respectively, supports this notion, and suggests that there was relatively little variation in scores within this group. However, the lack of statistical significance means that it is important to be careful when interpreting these results and conducting further analysis.

- **Question 9: "How strong was the feeling of the presence of other people in the virtual classroom?"**
  Based on participants' responses, their scores in Group 1 ($M = 1.8$, $SD = 0.84$) and Group 2 ($M = 2.4$, $SD = 0.54$) were compared using the two-tailed Mann-Whitney U-test. The U-value is 7, with the critical U-value at $p < 0.05$ being 2, and the z-score being -1.04447 at a p-value of 0.29834. These results indicate that there is no statistically significant difference in the feeling of presence of other people of the VR environment between the two groups at

Table 12: Likert Scale Results, Question 9

Group 1 (NE)		Group 2 (FE)	
Participant	Score	Participant	Score
1	2	1	2
2	3	2	3
3	1	3	2
4	2	4	2
5	1	5	3
Average	1.8	Average	2.4

the $p < 0.05$ level. It is important to note that while there was no significant difference, the mean score of 2.4 for group 2 suggests that participants rated the feeling of presence slightly higher than participants from Group 1 ($M = 1.8$). However, it can be concluded that both groups rated feeling of presence to be quite low. Besides, the relatively low standard deviation of 0.84 and 0.54, respectively, supports this notion, and suggests that there was relatively little variation in scores within this group. However, the lack of statistical significance means that it is important to be careful when interpreting these results and conducting further analysis.

5.3 Interview Results

This section presents the results of the interviews, specifically some of the responses of the participants, along with the corresponding analysis for each question and its outcomes. A complete list of participants' responses can be found in the Appendix A.

- **Question 1: "How did it feel to be in the virtual classroom?"**
  - "I felt immersed. It felt 3-dimensional."
  - "I was surprised that it felt more like a real classroom than I imagined."
  - "I catch myself doing the same things I would do in a normal classroom, like looking out of the window or looking behind you and looking at other people."

- "It was great!"
- "In fact, because everything looked "cartoonish", I didn't feel like I was in a real room. However, I was able to focus on the lecture."

Summary: Based on the answers, it can be concluded that the overall impression of the virtual classroom was positive. Participants generally felt like they were in a real classroom and were able to focus on the lecture. However, some participants mentioned feeling limited in their interaction with the environment. Additionally, some participants found the "cartoonish" environment less realistic, while others found it immersive and three-dimensional, which is interesting to see the variety of first impressions. Some participants reported being more focused in the virtual classroom because there were no distractions, while others found it less natural to behave. Overall, the responses suggest that the virtual classroom was a relatively successful simulation of a real classroom, but with some limitations and differences in the participants' experiences, that are going to be addressed in the next questions.

- **Question 2: "What were your initial thoughts and expectations about the VR environment before you began the experiment? How did these change as you went through the experience?"**
  - "I am admittedly biased against VR or specifically replacing reality with virtual reality, so coming here, I was already biased about the effectiveness of VR. When I first put on the headset, I felt somewhat real; it was cool, sitting and moving my head around was pretty accurate and natural."
  - "I had some expectations, but I was surprised how well I recognized the place."
  - "Since I had no experience with VR, I expected everything to be much more artificial and less interactive, but it turned out better than I expected."
  - "I think I expected to look less realistic. Like worse from the graphics, but it looked quite natural."

- "I didn't have any expectations. I have never used VR."

Summary: Based on the participants' responses, some had never experienced VR before and thus had no expectations. Those who had tried it before seemed impressed by the realism of the virtual environment, while others who were skeptical about VR were surprised by how well they recognized the virtual space (familiar environment). Participants who were not familiar with VR expressed surprise at the level of interaction and naturalness of the environment. Nevertheless, some participants who had prior experience with VR noted that they preferred to see people's faces over the camera rather than being in a virtual reality but not seeing their real faces. Some participants also expected to have more tools in the VR environment, such as a pen to write something down. Overall, participants seemed to have a mixed experience with the VR environment, and their initial expectations were either met or exceeded.

- **Question 3: "How did you find the interactions and presence of the teacher and other students in the virtual classroom? Were they realistic and engaging?"**
  - "No, they were realistic in their movements but not realistic in interaction. Well, I didn't seem to be able to interact with the other students or the teacher."
  - "I think they were partly realistic."
  - "The feeling of the teacher's presence was stronger than the presence of the students. The teacher's voice sounded alive because of pauses, hesitations, and speech errors."
  - "The students performed monotonous, repetitive actions, so the presence was almost un-felt."
  - "I can't say that they were realistic, but it gave an excellent imitation of the lesson. Visually, the presence of people helped me get deeper into the atmosphere."

Summary: Based on the responses, it seemed that the participants had varying experiences with the interactions and presence of the teacher and other students in the virtual classroom. Some found the movements and actions of the virtual characters to be realistic, while others noted that they felt too fixed or monotonous. Many participants found the lack of ability to interact with them. However, some found the presence of the virtual characters to be helpful in immersing them in the classroom environment. The realism and engagement of the virtual teacher seemed to have a stronger impact on the participants than that of the virtual students, with some noting that the teacher's voice and tone helped to enhance the sense of presence. Overall, while the virtual characters may not have been entirely realistic or engaging for all participants, their presence did contribute to the overall atmosphere and immersion in the virtual classroom environment.

- **Question 4: "How did the VR environment impact your engagement and motivation to learn the educational content?"**
  - "It strongly influenced me because it was a great way to get out of a state where you can't force yourself to sit down for a class or listen to a recorded lecture."
  - "I was able to focus on the lecture itself easily."
  - "I wonder if the environment made me pay attention or if I just wanted to get the correct answer later in the assessment."
  - "It was nice that I could stand up and look around without anyone noticing or feeling distracted. And I also like changing the seats and checking where I have the best view."
  - "I didn't need to be completely engaged to get the information I needed."

Summary: Based on the participants' answers, the VR environment positively impacted their engagement and motivation to learn the educational content. Participants mentioned that the immersive environment helped them focus on the lecture easily, as they could stay in the lecture for a longer time without any distractions. However, some participants mentioned that the VR environment alone did not transfer the motivation to learn. They needed to find the motivation within themselves. Participants also pointed out that they could not maintain 100% focus when the VR environment moved around, but they still felt engaged and motivated to learn. Overall, the participants' responses indicated that the VR environment positively impacted their engagement and motivation to learn, and it provided a unique and enjoyable experience compared to watching lectures on a laptop.

- **Question 5: "Was there anything that the VR environment allowed you to do that would be difficult or impossible in a traditional classroom setting?"**
  - "Sometimes it felt good to move around while learning."
  - "Being able to freely move during the lecture."
  - "Yes. Especially standing up and standing at the back of the class and watching while everybody is studying."
  - "It was nice that I could stand up and look around without anyone noticing or feeling distracted. And I also like changing the seats and checking where I have the best view."
  - "It would be unusual to stand up and move around the class when the lecturer is just talking. That feels good that you have this freedom."
  - "I felt very free. I could move and make different sounds. I was very relaxed and comfortable."

Summary: Based on the participants' responses, there are several unique abilities that VR provided: increased interaction with the virtual environment, the ability to freely move and explore during the lecture without being noticed, and a greater sense of immersion and presence. Many participants noted that they appreciated the ability to stand up, move around, and interact with virtual objects during the lecture, which they felt helped them to stay engaged and focused. Some also commented on the visual and auditory cues that made them feel like they were actually in a classroom with other people, which contributed to a sense of presence and social connection. Overall, the VR environment offered a more dynamic and engaging learning experience that could enhance cognitive processes and increase student motivation and interest.

- **Question 6: "Were there any specific aspects of the VR environment that you found particularly helpful or unhelpful for learning the educational content?"**

  - "Probably not; everything looked standard enough to imitate a lecture."
  - "I can assume that the movement is not very important, but then again, if the lecture is longer than this, I might like to walk around the room for a change of focus."
  - "I don't know which features made that possible, but it was very calm."
  - "Discipline and a sense of presence were very useful because if I was distracted, I remained in the learning environment. Like people who come to the library to better concentrate on learning."
  - "It was a little distracting that you could inspect the environment."
  - "Changing your seats and getting different angles on the slides were always also kind of helpful. That doesn't exist in Zoom."

  Summary: Based on the participants' responses, it seemed that the ability to move around in the VR environment was generally perceived as helpful for maintaining focus and avoiding distractions. Participants also appreciated the ability to change seats and angles to better view the educational content. On the one hand, the sense of discipline and presence provided by the VR environment was also found to be helpful, as it allowed participants to remain engaged and avoid distractions. On the other hand, some participants found certain aspects of the VR environment to be unhelpful or distracting, such as again the ability to inspect the environment, which could take away from the educational content. Some participants also noted that taking notes was not possible in the VR environment, which limited their ability to retain and review information.

- **Question 7: "What feedback would you give to improve the VR environment to enhance the learning experience?"**
  - "The teacher wasn't also opening his mouth; it was not moving."
  - "I would say the ability to interact with the instructor. Asking questions, talking with the instructor. Something like that."
  - "Maybe an easier way to manipulate the slides of the lecture."
  - "I would change something around the teacher. The lecturer could show some emotions."
  - "Rewinding or fast-forwarding is just not needed because, in real life, you cannot rewind a lecture. I understand that this prototype is a video player, but just the absence of such a function will help create discipline like in real classes. If you missed something, then you missed it."
  - "I would like to feel more movement so that I can move in the real world and in VR at the same time. Of course, to be safe within my room."

  Summary: Based on the participants' responses, some suggested adding more interactive elements, such as the ability to ask questions and communicate with the instructor. Others suggested improving the graphics or adding more realistic shades to figures. Additionally, some participants noted the importance of the lecturer being more dynamic, showing emotions, and interacting with the students. Yet, several students also pointed out that certain features, such as the ability to rewind or fast-forward lectures, might not have been necessary and could potentially have detracted from the discipline of real-life classes. Overall, it seemed that participants believed that improving interactivity, realism, and engagement were key factors in enhancing the learning experience in a VR environment.

- **Question 8: "How do you see the use of VR technology in education evolving in the future?"**

- "I would not mind watching lectures in this format during a pandemic, but the accessibility of such devices is still low."
- "Having more practical ways to interact with 3d objects, maybe perform certain crafting."
- "It would be good to access certain topics you don't have. Like asking to explain different engineering topics that weren't provided by the teacher initially."
- "It has a lot of potential. But I don't know if it would be well used by a regular user."
- "I have great hopes, and I am extremely excited about education in VR."
- "In the future, I could see it as a substitute when physical learning is absent."

Summary: Based on the participants' answers, they expressed excitement and optimism about the possibilities of VR in education, particularly in terms of providing practical ways to interact with 3D objects and offering a substitute for physical learning when it is not possible. However, the accessibility of VR devices remained a barrier for some participants, and there were concerns about the lack of real-life interactions and tactile feedback. Some participants also emphasized the importance of interactive features. Overall, the responses indicated that VR technology had a promising future in education. Thus, the development of more affordable and accessible VR devices, along with the integration of interactive features, could have made VR a valuable tool for educational institutions and online learning platforms.

- **Question 9: "Are there any specific features that you would like to see in a VR classroom?"**
  - "I didn't have arms or body, so I would improve that."
  - "Note making."
  - "I would like to see the possibility of customizing the room. (free choice between rooms, or editing the current room: light, colors, etc.)"

- "Whispering to other users in the multiplayer virtual classroom."
- "I was expecting more tools, for example, to write something down or have a pen or something else."
- "I would like to be able to voice input and output with a response through a conversational agent, such as an AI."

Summary: The participants' responses suggested that there were several key elements that might have enhanced their learning experience. They expressed a desire for interaction with the lecturer or instructor, such as seeing their actual face and mouth moving, and the ability to customize the virtual environment by choosing different rooms, editing lighting and colors, and walking around familiar places on campus. Participants often expressed a need for practical tools, such as note-making, highlighting, and voice input and output with an AI response. They wanted to have improved body and arm tracking to create a more realistic VR experience. Overall, participants wanted a VR classroom that allowed for customization, interaction, practical tools, and a more realistic VR experience.

5.4 Results Discussion

5.4.1 Knowledge Assessment and Likert Survey

According to the results, there are promising advantages of utilizing virtual reality technology to enhance student's learning process. Presumably, the outcomes suggest that creating virtual representations of familiar educational institutions may augment the retention and comprehension of educational content. While the results are insightful, there is still a chance that the experiment may have overlooked some potential side effects for unspecified conditions.

Nonetheless, this study has implications for the design of educational environments in the future, as it emphasizes the significance of recognition and its impact on learning outcomes. Before further exploration, it is important to remember that conclusions drawn from the following results should be approached with caution, as future research may bring new information or perspectives that could alter the presented understanding of things.

Considering the results of all three measurements together, they can be interpreted as follows. The t-test of post-test results revealed that recognition of virtual reality had a possible positive impact on the quality of learning compared to a novel virtual environment, as indicated by the higher scores of participants from the university's classroom replica. Besides, it is crucial to acknowledge that further interpretation of the Likert survey may determine the factors that influenced the improvement in understanding the educational material.

The primary objective of the Likert survey was to identify the factors within the virtual environment that could potentially affect academic performance based on participants' perceptions. However, the statistical analysis conducted using the Mann-Whitney U test failed to confirm any apparent relationship between the selected factors. Therefore, this thesis can not conclude with certainty that familiarity with the environment could provide better educational performance. This could be explained by several limitations, such as the small sample size of only 10 participants, their motivation and prior knowledge, or the potential influence of other factors not included as a specified stimulus. Nevertheless, when examining the difference in averages for each question, it is worth noting that participants from a familiar environment had a higher average score in 4 out of 9 Likert survey questions about realism, immersiveness, likeliness to use these technologies in the future, and the feeling of the presence of other students. At the same time, the opposite group scored higher on average in only two questions: comfort with VR and naturalism of interactions. Other domains (engagement, ease of use, facilitation of VR on lecture understanding) have demonstrated equal average scores in both groups. Overall, the virtual replica of the real classroom received higher ratings, although the differences in average results were minimal.

5.4.2 Interview Outcomes

As this study also analyzed interviews with participants regarding their experiences in a virtual classroom, it provided several key findings. Participants generally had a positive impression of the virtual classroom, considering it an accurate simulation of a real classroom and feeling fully immersed in the environment. However, some participants felt limited in their interactions within the virtual space and preferred real faces over virtual avatars. The presence of the teacher and other students was found to be realistic and engaging, although opinions varied on the movements and actions of virtual characters.

The VR environment had a positive impact on participants' engagement and motivation to learn. They found it easier to focus on the lecture without distractions and appreciated the freedom to explore the environment and change seats. Nonetheless, participants acknowledged that their motivation still depended on personal factors rather than solely on the VR environment.

Participants highlighted the unique advantages of the VR environment, including increased interaction with the virtual world, freedom of movement and exploration, and a greater sense of immersion and presence. The ability to stand up, move around, and interact with virtual objects was valued as it contributed to their engagement and focus.

Various aspects of the VR environment were deemed helpful for learning, such as the ability to optimize views by moving and changing seats. The sense of discipline and presence facilitated engagement. However, some participants found certain aspects unhelpful or distracting, such as inspecting the environment or the absence of note-taking capabilities.

To enhance the learning experience, participants recommended improving interactivity, realism, and engagement in the VR environment. They desired more interactive elements, such as the ability to ask questions and communicate with the instructor, as well as improvements in graphics and the behavior of virtual characters. Striking a balance between interactivity and minimizing distractions was also seen as crucial. That is interesting that students seek to get a higher realism of non-playable character in the simulation, as it was stated in Schwind's (2018) research, a high realism can create increasing anxiety and negative mood, as such concept as "uncanny valley." Described as the uncomfortable feeling or unease we may experience when we encounter something that looks almost, but not quite, like a human (Schwind et al., 2018).

Participants expressed optimism about the future of VR technology in education, recognizing its potential to provide practical ways to interact with 3D objects and act as a substitute for physical learning when necessary. However, accessibility to VR devices and concerns about real-life interactions and tactile feedback were mentioned as barriers. Interactive features were deemed crucial for effective utilization of VR in education.

When asked about specific features they would like to see in a VR classroom, participants emphasized the importance of interaction with the instructor, customization options for the virtual environment, practical tools for note-taking and highlighting, improved body and arm tracking, and visualizations connecting to brain or body science.

In conclusion, participants had a positive overall experience in the virtual classroom, finding it immersive and engaging. The VR environment positively impacted their engagement and motivation to learn, offering unique advantages not found in traditional classrooms. While there were suggestions for improvement, participants expressed optimism about the future of VR technology in education, emphasizing the need for interactivity and enhanced realism to further enhance the learning experience.

Chapter 6

Conclusion

This thesis aimed to investigate the impact of virtual reality (VR) technology on students' understanding of educational material by comparing their experiences in a familiar environment, a replica of a university classroom, to a novel virtual environment. The results discussed in the previous section shed light on the main findings, implications for education and future research, as well as the limitations of the study. Based on the comprehensive analysis of the data, this conclusion chapter summarizes the key insights and draws final remarks.

6.1 Summary of Main Findings

The findings of this study suggest promising advantages of utilizing VR technology to enhance the learning process of students. The creation of virtual representations of familiar educational institutions, such as the university classroom replica, appears to augment the retention and comprehension of educational content. Participants in the familiar environment demonstrated higher scores in the knowledge assessment, indicating a possible positive impact on the quality of learning compared to the novel virtual environment.

Additionally, the Likert survey explored participants' perceptions of various factors within the VR environment that could potentially affect academic performance. While statistical analysis using the Mann-Whitney U test did not confirm a clear relationship between the selected factors and educational performance, participants from the familiar environment generally had higher average scores in questions related to realism, immersiveness, likeliness to use the technology in the future, and the feeling of the presence of other students. On the other hand, the opposite group scored higher on average in questions regarding comfort with VR and naturalism of interactions. Other domains, such as engagement, ease of use, and facilitation of VR on lecture understanding, demonstrated similar average scores in both groups. Overall, the virtual replica of the real classroom received higher ratings, although the differences in average results were minimal.

The analysis of interviews with participants provided further insights into their experiences in the virtual classrooms. Participants generally had a positive impression of the VR environment, considering it an accurate simulation of a real classroom and feeling fully immersed. The VR environment positively impacted their engagement and motivation to learn, allowing them to focus on the lecture without distractions and offering freedom of movement and exploration. The ability to interact with virtual objects and optimize views through seat changes were seen as helpful for learning. Participants expressed optimism about the future of VR technology in education, recognizing its potential for practical interaction with 3D objects and as a substitute for physical learning when necessary.

6.2 Implications for Education and Future Research

The implications of this research for education are significant, as it emphasizes the importance of recognition and familiarity in designing educational environments. The findings suggest that virtual replicas of familiar institutions can enhance the learning experience, potentially leading to improved retention and comprehension of educational content. This has implications for the design and development of VR-based educational tools and platforms, indicating the potential benefits of recreating real-world learning environments in virtual space.

Future research in this field should further explore the relationship between recognition, familiarity, and educational outcomes in VR environments. This study has laid the foundation for understanding the impact of familiarity, but further investigations with larger sample sizes and diverse participant groups are needed to establish more conclusive results. Additionally, exploring other factors that may influence educational performance in VR, such as motivation, prior knowledge, and individual differences, could provide a more comprehensive understanding of the learning process in virtual classrooms.

Moreover, the study highlights the need for improvements in interactivity, realism, and engagement within VR environments. Participants expressed their desire for more interactive elements, including the ability to communicate with instructors, customize the virtual environment, and utilize practical tools for note-taking and highlighting. Enhancements in graphics, virtual character behavior, and body and arm tracking were also suggested. Future research should focus on addressing these findings to create more immersive and effective VR learning experiences.

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Appendix A

Appendix - Measurements

A.1 Pre- Post- Knowledge Assessment Questions

The list of pre and post-testing questions consists of **(correct answer in bold)**:

1. What is economics defined as by Lionel Robbins?

   (a) **The study of how human behavior exists as a relationship between given ends and scarce means with alternative uses**

   (b) The study of how society manages its abundant resources

   (c) The study of how individuals use limited resources to achieve unlimited wants

   (d) The study of how people interact with each other to achieve a common goal

   (e) I don't know *(pre-test only)*

2. What is the meaning of scarcity in economics?

   (a) Abundance of goods and services in a society's resources

   (b) **Limited goods or services of a society's resources**

   (c) Unlimited goods or services in a society's resources

   (d) Availability of unlimited resources to achieve unlimited wants

   (e) I don't know *(pre-test only)*

3. What is an opportunity cost in economics?

   (a) The cost of obtaining something after giving up a desired end

   (b) The cost of not having something desired

   (c) **What must be given up to obtain something**

   (d) The cost of having everything one wants

   (e) I don't know *(pre-test only)*

4. What does the concept of a marginal change in economics refer to?
   (a) Large adjustments made to a plan
   (b) **Small adjustments made to a plan**
   (c) The study of human behavior as a relationship between given ends and scarce means with alternative uses
   (d) The study of a society managing its abundant resources
   (e) I don't know *(pre-test only)*

5. What type of economic system is a market economy?
   (a) **A capitalist economic system with free competition and prices determined by interactions in the marketplace, with no central planning**
   (b) A socialist economic system with government control and prices determined by the state
   (c) An economic system with prices determined by government agencies
   (d) An economic system with prices determined by the marketplace but with central planning
   (e) I don't know *(pre-test only)*

6. What can be a reason for low productivity in a society?
   (a) Laziness or weakness
   (b) Excess tools, technology, and knowledge
   (c) Excess tools, technology, and knowledge
   (d) **Lack of tools, technology, and knowledge**
   (e) I don't know *(pre-test only)*

7. What is inflation in economics?
   (a) A decrease in the overall level of prices in the economy
   (b) **An increase in the overall level of prices in the economy**
   (c) A decrease in the prices of a single product or industry
   (d) An increase in the prices of a single product or industry
   (e) I don't know *(pre-test only)*

8. What is the relationship between productivity and standard of living?
   (a) Productivity has no impact on the standard of living
   (b) An increase in productivity leads to a decrease in the standard of living
   (c) **An increase in productivity leads to an increase in the standard of living**
   (d) A decrease in productivity leads to an increase in the standard of living
   (e) I don't know *(pre-test only)*

9. What does externality refer to in economics?
   (a) The cost or benefit to a third party involved in an action
   (b) **The cost or benefit to a third party not involved in an action**
   (c) The cost or benefit to a first party involved in an action
   (d) The cost or benefit to a second party involved in an action
   (e) I don't know *(pre-test only)*
10. What does the term "market" refer to in economics?
   (a) A physical place for trade
   (b) Promotion of a product or idea
   (c) **An economy where decisions about economic activities are made by businesses and households**
   (d) A central government making economic decisions
   (e) I don't know *(pre-test only)*
11. What does the concept of the invisible hand refer to?
   (a) **The idea that as individuals pursue their self-interest, it leads to an overall benefit for society**
   (b) A small group or individual having too much control over a market
   (c) A side effect of an economic decision that affects a third party
   (d) The responsibility of the government to ensure the economy runs efficiently and equitably for all members of society
   (e) I don't know *(pre-test only)*
12. What is the government's responsibility towards the economy?
   (a) **To maintain order and enforce rules**
   (b) To ensure the economy runs efficiently for some members of society
   (c) To only focus on increasing the size of the economy
   (d) To not interfere with the economy at all
   (e) I don't know *(pre-test only)*
13. What is an incentive in economics?
   (a) **An event that motivates people to act**
   (b) A negative impact on someone's behavior
   (c) A payment in exchange for goods or services
   (d) A physical item that represents the reward
   (e) I don't know *(pre-test only)*
14. According to the text, what can incentives change in people's behavior?
   (a) Physical actions
   (b) Emotional state

   (c) Moral standing
   (d) **Desired outcomes**
   (e) I don't know *(pre-test only)*

15. How does trade affect the growth of societies?
   (a) By limiting the number of goods and services available
   (b) By causing societies to focus on single products and neglect others
   (c) **By enabling individuals to specialize in what they do best**
   (d) By making societies stagnant and unproductive
   (e) I don't know *(pre-test only)*

A.2 Interview Quotes

Full list of interview outcomes:

1. **Question 1: How did it feel to be in the virtual classroom?**
   - "The virtual classroom felt like an actual classroom. However, my interaction with the environment was limited"
   - "it was great."
   - "I think people and their movement seemed realistic;"
   - "I felt immersed. It felt 3-dimensional."
   - "I was surprised that it felt more like a real classroom than I imagined."
   - "I had my hands here at the table and watching people speak and watching the slides; that was quite normal."
   - "I catch myself doing the same things I would do in a normal classroom, like looking out of the window or looking behind you and looking at other people."
   - "I was more focused because there were no real destructors like actual human people and a bit more uncomfortable because it was less natural to behave."
   - "It was good, but I didn't feel it was real in the environment."
   - "In fact, because everything looked cartoonish, I didn't feel like I was in a real room. However, I was able to focus on the lecture."
   - "It was normal. It felt like in an actual room; psychologically, I felt like I was at a lecture. My psychological barrier was that I had to sit out like in a real class. Wait until the end, and don't leave the process unfinished."
2. **Question 2: What were your initial thoughts and expectations about the VR environment before you began the experiment? How did these change as you went through the experience?**
   - "I am admittedly biased against VR or specifically replacing reality with virtual reality, so coming here, I was already biased about the effectiveness of VR. When I first put on the headset, I felt somewhat real; it was cool, sitting and moving my head around was pretty accurate and natural."

- “I haven’t tried good VR before, but this was maybe the best VR I have ever tried.”
- “Seeing people’s faces over the camera would be better than being in a virtual reality but not seeing their real faces. That is why zoom would be better.”
- “My opinion hasn’t changed against VR, except it is probably way cooler than I expected it to be.”
- “I had some expectations, but I was surprised how well I recognized the place.”
- “I also get to sit when I usually sit. It felt comfortable.”
- “Since I had no experience with VR, I expected everything to be much more artificial and less interactive, but it turned out better than I expected.”
- “I think I expected to look less realistic. Like worse from the graphics, but it looked quite natural.”
- “I thought I would be alone in the room and with only a professor. And I did not expect the other students to be there. But I think it was good that other people were there.”
- “Maybe I expected more people and a bit more realness because the professor didn’t even talk.”
- "I was expecting to have more tools, for example, to write something down or have a pen or something else."
- "I didn’t have many expectations."
- "I didn’t have any expectations. I have never used VR."

3. **Question 3: How did you find the interactions and presence of the teacher and other students in the virtual classroom? Were they realistic and engaging?**

   - "No, they were realistic in their movements but not realistic in interaction. Well, I didn’t seem to be able to interact with the other students or the teacher."
   - "So it kind of did, to some extent, feel like I was a ghost over there, that nobody else pays attention to me, nobody else acknowledges me."
   - "I think they were partly realistic."
   - "It was way better than having no people inside."
   - "From the graphics, it was clear that people were unreal, so the presence was not felt."
   - "The feeling of the teacher’s presence was stronger than the presence of the students. The teacher’s voice sounded alive because of pauses, hesitations, and speech errors."
   - "The students performed monotonous, repetitive actions, so the presence was almost un-felt."
   - "I could see that they were writing, typing, and listening. But they felt too fixed."

- "It was good that there was a person in front, but he didn't speak with his mouth, and I saw that."
- "I wondered if the mouth would be moving from the professor."
- "I was confused by that at the beginning. I mean, you get used to it. It would feel more realistic if the mouth was moving."
- "And other students felt quite realistic at first glance. But then I looked at the one guy the blonde hair for a while, and he was typing on a computer, and he was always doing the same motion."
- "I think it was good that they were not engaging because otherwise, I couldn't focus better. I think I would like the professor to be more realistic so he was not spreading any enthusiasm or motivation."
- "It was realistic, not in shape. Realistic in the actions, for example, one of them was typing on the computer, and the others just like paying attention."
- "Probably not because I could not communicate and contact them in any way."
- "But their presence helped to immerse me in the class environment."
- "I can't say that they were realistic, but it gave an excellent imitation of the lesson. Visually, the presence of people helped me get deeper into the atmosphere."
- "The teacher was definitely not engaging; maybe if he had gesticulated more, or would be more emotional, however, what I saw was completely enough for me to immerse myself in the atmosphere of the class, where I do not influence the whole process."
- "The presence of other characters was the strongest factor for immersion for me."

4. **Question 4: How did the VR environment impact your engagement and motivation to learn the educational content?**

    - "It strongly influenced me because it was a great way to get out of a state where you can't force yourself to sit down for a class or listen to a recorded lecture."
    - "From start to finish, It felt like a lecture, which allowed me to be there from start to finish without any interruptions."
    - "I was able to focus on the lecture itself easily."
    - "I wonder if the environment made me pay attention or if I just wanted to get the correct answer later in the assessment."
    - "Focus was better, but the motivation needed to be transferred."
    - "Definitely, I would prefer to watch in this way than on my laptop because you were also more in that situation."
    - "It was nice that I could stand up and look around without anyone noticing or feeling distracted. And I also like changing the seats and checking where I have the best view."

- “And I think the VR environment, compared to watching lectures online at home, if I have the headset on, I think I’m more likely to stay in the lecture. That’s great because if I sit in front of my computer at home, I can just stand up and go, basically.”
- "The only thing I have is, like, when it starts moving around, I know that I’m not listening, like, 100% anymore, but at least, like, 70% and not 0%. Yeah, that’s great. So it helps stay motivated.”
- “It affected me positively.”
- “Since this was my first experience, I really wanted to walk around and explore the environment. It could have a certain impact on my motivation to learn: neither good nor bad impact.”
- “I was able to pay more attention than watching the lecture at home from my laptop.”
- “I didn’t need to be completely engaged to get the information I needed.”
- “I would have tried to make it more of a conversation by asking questions to the instructor and so on.”

5. **Question 5: Was there anything that the VR environment allowed you to do that would be difficult or impossible in a traditional classroom setting?**

    - "I feel like there was more interaction with the actual environment in VR, so even if not with the other people, there was interaction with the environment."
    - "You seem to be inside a classroom instead of sitting in your apartment and looking at a computer screen. So visually, it does seem to be like you’re inside a classroom."
    - "Looking at the screen of the lecturer."
    - "Sometimes it felt good to move around while learning."
    - "I think moving is extremely important for cognitive processes."
    - "Being able to freely move during the lecture."
    - "Standing up, coming way too close to NPCs."
    - "Yes. Especially standing up and standing at the back of the class and watching while everybody is studying."
    - "it allowed me to be in that room with other people, with the feeling of other people, but more the slight feeling of other people, but still without being distracted by them. Perfect balance."
    - "It would be unusual to stand up and move around the class when the lecturer is just talking. That feels good that you have this freedom."
    - "High mobility."
    - "My attention was limited to the space of the virtual environment. I may have been distracted by the objects, but I remained concentrated on the lecture. At home, I often distract myself with various subjects that knock me out of the educational rhythm."
    - "I felt very free. I could move and make different sounds. I was very relaxed and comfortable."

6. **Question 6: Were there any specific aspects of the VR environment that you found particularly helpful or unhelpful for learning the educational content?**

   - "Probably not; everything looked standard enough to imitate a lecture."
   - "I can assume that the movement is not very important, but then again, if the lecture is longer than this, I might like to walk around the room for a change of focus."
   - "I'm glad I could move around in VR because I don't want to spend all my time in one spot."
   - "I couldn't do anything else to maximize the input that I'm getting."
   - "Moving around helped me intentionally skip the repetitive information by just changing my focus but not leaving the flow. Because in a real class, I must listen to it every time so I won't lose track."
   - "I don't know which features made that possible, but it was very calm."
   - "what you can't do is like taking notes."
   - "It was a little distracting that you could inspect the environment."
   - "Discipline and a sense of presence were very useful because if I was distracted, I remained in the learning environment. Like people who come to the library to better concentrate on learning."
   - "At home, I can see the same slides on the monitor but get distracted by things like bed, food, etc."
   - "Just the Situatedness of being in the space."
   - "I think the slides, I think they were cool because they were actually being projected onto the screen and not just pictures on your monitor."
   - "Changing your seats and getting different angles on the slides were always also kind of helpful. That doesn't exist in Zoom."
   - "I was looking out of the window, but at least it was like, in the classroom window, my attention was still within the classroom and not on other things that are outside the classroom."
   - "However, it was repetitive, and they were making the same things over and over again, but it still looked pretty cool, like the student typing and writing notes."

7. **Question 7: What feedback would you give to improve the VR environment to enhance the learning experience?**

   - "The teacher wasn't also opening his mouth; it was not moving."
   - "Moving my head a little bit was jerky. When I move the joystick to the left, then it moves by so much, and then I can't do anything in between."
   - "I would say the ability to interact with the instructor. Asking questions, talking with the instructor. Something like that."
   - "It was disappointing that I couldn't interact with other people because they were not real."
   - "Sometimes I interact with the people during real classes."

- "e.g., changing seats, I could only sit in 3 different seats. Standing and walking around the class is something that I was able to do, but I shouldn't have had that option because it might lead to more distraction."
- "To make a lecturer more dynamic."
- "Pointing at the slides, at least."
- "I would add interactivity to lecture management. For example, I got stuck in the window and did not hear certain material and would like to return to it, but I could not."
- "Aesthetically, I see no reason to improve the graphics because I doubt that it significantly increased my immersiveness in the virtual environment."
- "Also, communication with artificial players is not required because this will also distract me from the lesson."
- "The lecturer was quite passive. I would improve that."
- "Maybe an easier way to manipulate the slides of the lecture."
- "taking notes, making questions in the middle so you have to interact with the material that can help."
- "I would change something around the teacher. The lecturer could show some emotions."
- "More tools and more realistic shades of the figures. That would be especially important for lecturers because the most attention is on them: both professor and slides."
- "I would like to feel more movement so that I can move in the real world and in VR at the same time. Of course, to be safe within my room."
- "Rewinding or fast-forwarding is just not needed because, in real life, you cannot rewind a lecture. I understand that this prototype is a video player, but just the absence of such a function will help create discipline like in real classes. If you missed something, then you missed it."

8. **Question 8: How do you see the use of VR technology in education evolving in the future?**

- "I would not mind watching lectures in this format during a pandemic, but the accessibility of such devices is still low."
- "Having more practical ways to interact with 3d objects, maybe perform certain crafting."
- "It would be good to access certain topics you don't have. Like asking to explain different engineering topics that weren't provided by the teacher initially."
- "I could imagine instead of watching the lecture on the laptop when I missed a lecture, then I could watch it in this way, maybe even write something down in VR because that would be a problem."
- "I think this will be possible and made accessible to the public maybe in ten years or so."

- "There are already online universities, and from my own studying experience, it's very hard to stay focused. And for online universities, it could be a nice tool, and also if it gets interactive."
- "It has a lot of potential. But I don't know if it would be well used by a regular user.
- "I like that such technologies exist, and I would like to see how such things will be implemented in educational institutions."
- "I have great hopes, and I am extremely excited about education in VR."
- "Portraying object in 3d scale is a very immersive way of learning."
- “In the future, I could see it as a substitute when as a good substitute when physical learning is absent.”
- "It's missing a lot of actual real-life interaction. Like being able to feel things, interacting fully with the environment, with every object, as if it was actually there, talking to people, social interactions, and so on."

9. **Question 9: Are there any specific features that you would like to see in a VR classroom?**

   - "Seeing the face of the real instructor or their mouth moving to the audio would be nice."
   - "I didn't have arms or body, so I would improve that."
   - "Interaction with a lecturer."
   - "Note making."
   - "I would like to see the possibility of customizing the room. (free choice between rooms, or editing the current room: light, colors, etc.)"
   - "Whispering to other users in the multiplayer virtual classroom."
   - "Raising your hand to ask questions, but I think it's also interaction."
   - "But visualizations would be nice to see in VR, like neuropsychology or something connected to brain or body science.
   - "I was expecting more tools, for example, to write something down or have a pen or something else."
   - "I really wanted to take notes because that was important. Especially like, not necessarily many words, just like highlighting or something."
   - "I'd like to walk around the familiar places on campus."
   - "It would probably be great to use such technologies now."
   - "Ability to invite other users to the simulation."
   - "Note making."
   - "I would like to be able to voice input and output with a response through a conversational agent, such as an AI."

Appendix B

Appendix - Prototype

B.1 Unity Custom C# Scripts

Regarding the code used for this thesis, the Unity project repository can be found here:
`https://github.com/ivanmakesgames/masters-thesis`
or see code snippets below (Note: Napespaces such as "using UnityEngine" are not included in code snippets, consider it when using this code for your projects):

1. WristUI.cs

```
public class WristUI : MonoBehaviour
{
    public InputActionAsset inputActions;

    private GameObject _wristUI;
    private InputAction _menu;

    private void Start()
    {
        _wristUI = gameObject;
        _wristUI.SetActive(false);
        _menu = inputActions.FindActionMap("XRI LeftHand").FindAction("Menu");
        _menu.Enable();
        _menu.performed += ToggleMenu;
    }

    private void OnDestroy()
    {
        _menu.performed -= ToggleMenu;
    }

    public void ToggleMenu(InputAction.CallbackContext context)
    {
        _wristUI.SetActive(!_wristUI.activeSelf);
    }
}
```

2. VolumeControl.cs

```
public class VolumeControl : MonoBehaviour
{
    public VideoPlayer videoPlayer1;
    public VideoPlayer videoPlayer2;
    public Slider volumeSlider;

    private void Start()
    {
        volumeSlider.onValueChanged.AddListener(AdjustVolume);
    }

    public void AdjustVolume(float volume)
    {
        videoPlayer1.SetDirectAudioVolume(0, volume);
        videoPlayer2.SetDirectAudioVolume(0, volume);
    }
}
```

3. PauseTimeAndVideos.cs

```
public class PauseTimeAndVideos : MonoBehaviour
{
    public VideoPlayer videoPlayer1;
    public VideoPlayer videoPlayer2;
    private Button button;
    private bool isPaused = false;

    private void Start()
    {
        button = GetComponent<Button>();
        button.onClick.AddListener(PauseResumeTime);
    }

    private void PauseResumeTime()
    {
        if(!isPaused)
        {
            Time.timeScale = 0;
            videoPlayer1.Pause();
            videoPlayer2.Pause();
            isPaused = true;
        }
        else
        {
            Time.timeScale = 1;
            videoPlayer1.Play();
            videoPlayer2.Play();
            isPaused = false;
        }
    }
}
```

4. SetXROriginPosition.cs (*aka "Camera Reset Feature", similar scripts were used for different XRRigs in the scene*)

```
public class SetXROriginPosition : MonoBehaviour
{
```

```
    [SerializeField] private Transform xrOriginTransform;

    private void Update()
    {
        xrOriginTransform.position = new Vector3(xrOriginTransform.position.x,
        -0.62f, xrOriginTransform.position.z);
    }
}
```

5. AnimateHandOnInput.cs (*Gestures and hands animation*)

```
public class AnimateHandOnInput : MonoBehaviour
{
    public InputActionProperty pinchAnimationAction;
    public InputActionProperty gripAnimationAction;
    public Animator handAnimator;

    // Start is called before the first frame update
    void Start()
    {

    }

    // Update is called once per frame
    void Update()
    {
        float triggerValue = pinchAnimationAction.action.ReadValue<float>();
        handAnimator.SetFloat("Trigger",triggerValue);

        float gripValue = gripAnimationAction.action.ReadValue<float>();
        handAnimator.SetFloat("Grip", gripValue);
    }
}
```

6. XROriginSwitcher.cs (*This script allows to switch user's active state to sitting, standing, walking, changing seats*)

```
public class XROriginSwitcher : MonoBehaviour
{
    public GameObject currentXROrigin;
    public GameObject nextXROrigin;
    private Button button;

    private void Start()
    {
        button = GetComponent<Button>();
        button.onClick.AddListener(SwitchXROrigin);
    }

    private void SwitchXROrigin()
    {
        currentXROrigin.SetActive(false);
        nextXROrigin.SetActive(true);

        GameObject temp = currentXROrigin;
        currentXROrigin = nextXROrigin;
        nextXROrigin = temp;
    }
}
```

7. SceneLoader.cs (*only used in "Testing" environment to load an assigned classroom*)

```
public class SceneLoader : MonoBehaviour
{
    public string sceneName;
    private Button button;

    private void Start()
    {
        button = GetComponent<Button>();
        button.onClick.AddListener(LoadScene);
    }

    public void LoadScene()
    {
        SceneManager.LoadScene(sceneName);
    }
}
```

Important: changes made to original XR Interaction Toolkit package are not included in the list. For more information head to github page (Polivanov, 2023)