VR Engagement Rates

by

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Declaration of Authorship

I, David Irwin , declare that this thesis titled, 'VR Retention Rates' and the work presented in it are my own. I confirm that:

- This work was done wholly or mainly while in candidature for an undergraduate degree at Munster Technological University.
- Where any part of this thesis has previously been submitted for a degree or any other qualification at Munster Technological University or any other institution, this has been clearly stated.
- Where I have consulted the published work of others, this is always clearly attributed.
- Where I have quoted from the work of others, the source is always given. With the exception of such quotations, this project report is entirely my own work.
- I have acknowledged all main sources of help.
- Where the thesis is based on work done by myself jointly with others, I have made clear exactly what was done by others and what I have contributed myself.

Signed: David Irwin

Date: 26/12/2021

Munster Technological University

Abstract

Faculty of Engineering and Science
Department of Computer Science

Bachelor of Science

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Virtual Reality is an emerging technology sought after by various companies to create new and meaningful ways to interact, collaborate and educate. Therefore, the objective of this thesis is to explore the latter in respect to formal education. The goal of this paper is to develop an educational app using virtual reality technology in order to study and report on it's impact on student engagement. This paper will serve as a proof-of-concept for educators to reference when looking for new ways to utilise technology in higher education.

The research of this paper will mainly focus on what other researchers have already conducted with respect to VR in education in order build upon their findings.

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Abbreviations

VR	**V**irtual **R**eality
VRS	**V**irtual **R**eality **S**pectatorship
UE	**U**nreal **E**ngine
PC	**P**ersonal **C**omputer
SDK	**S**oftware **D**evelopment **K**it
IDE	**I**ntegreted **D**evelopment **E**nvironment
API	**A**pplication **P**rogramming **I**nterface
XR	**E**xtended **R**eality
GPU	**G**raphics **P**rocessing **U**nit
FPS	**F**rames **P**er **S**econd
MVP	**M**inimum **V**iable **P**roduct
SQL	**S**tructured **Q**uery **L**anguage
UI	**U**ser **I**interface

For/Dedicated to/To my...

Chapter 1

Introduction

Virtual reality is a technology that has yet to reach mainstream adoption. There have been many false starts where the headsets could not deliver on the promises made. However, we have come a long way since then, and many strides have been made to reach the potential of this tech that was only theorised about until now. With many new technological breakthroughs since, it is time to revisit VR with respect to education and see if it finally has the potential to deliver a meaningful experience.

1.1 Motivation

I have always found myself gravitating towards new ideas and novel solutions to problems in the tech industry. My fear of being left behind due to the rapid change this sector goes through has led me to look forward to trying and anticipating the next technological revolution in personal computing. From listening to industry experts such as Tim Cook, CEO of Apple & Tim Sweeney, CEO of Epic Games, I have realised that this next phase may be virtual reality technology. My admiration for both CEOs has inspired me to contribute to this domain in any way I can. What led me to decide to focus on the education aspect of VR ultimately was the level of change that COVID put on higher education. Before undertaking this project, I completed a year entirely remotely at MTU. During this year, I questioned whether there exists a better approach to remote learning that can give students a greater sense of presence with fellow peers and lecturers. Naturally, this led me to question whether or not VR can first accommodate the most important aspect of college, learning. Therefore, I decided to develop an application to answer this question.

1.2 Contribution

For this project, I am utilizing emerging technologies such as VR hardware and combining that with game development and backend software (MySQL). This system hopes to lay the foundation for future researchers by providing insights into this new technology and how it can be used to provide a new method of learning with respect to education. With this project, I want to provide an application that other researchers can download and use to aid their own studies in this domain. The application built in this project will be available to anyone who owns the suggested VR headset.

1.3 Structure of This Document

- Chapter 1 of this document serves as an introduction to this research project and the motivation behind it.
- In chapter 2, we will conduct background research to gain an understanding of what virtual reality technology is, the importance of such technology and the potential impacts it has on not only the education industry but real estate, e-commerce and sports.
- In chapter 3, the research problem is defined as well as the objectives and requirements of this paper.
- Chapter 4 pertains to the approach taken in order to answer this research question and details the technologies used. Such as game engines and programming languages, risks proposed and an evaluation plan to gauge the project's success.
- Lastly, chapter 5 sums up the conclusions made from the research phase and future work.

Chapter 2

Background

2.1 Introduction

This chapter comprises of five sections. Section 2.1 introduces virtual reality technology and my view on its importance. Section 2.2 pertains to VR technology in general, i.e. its impact on other industries. Section 2.3 deals with VR and education, the main topic of this research paper. Section 2.4 is about VR frameworks. Finally, section 2.5 conveys student engagement.

2.1.1 Thematic Area within Computer Science

This project aims to develop a VR educational app and analyse its effectiveness. Therefore the core computer science topic that this project falls under is software development. Before delving into the proponent of educational virtual reality apps, it is appropriate to convey what virtual reality actually is and how it works. According to the Britannica encyclopedia, virtual reality is the use of computer modelling and simulation that enables a person to interact with an artificial three-dimensional (3-D) visual or other sensory environment. [1]. In other words, it gives users the ability to experience computer programs as though we are physically inside of them (see Figure 2.1). Furthermore, with a virtual reality headset that acts as our window into the VR world, the user becomes fully immersed in the computer gendered 3D environment [2]. This level of immersion gives the user an experience that cannot be replicated with the use of solely a computer and monitor.

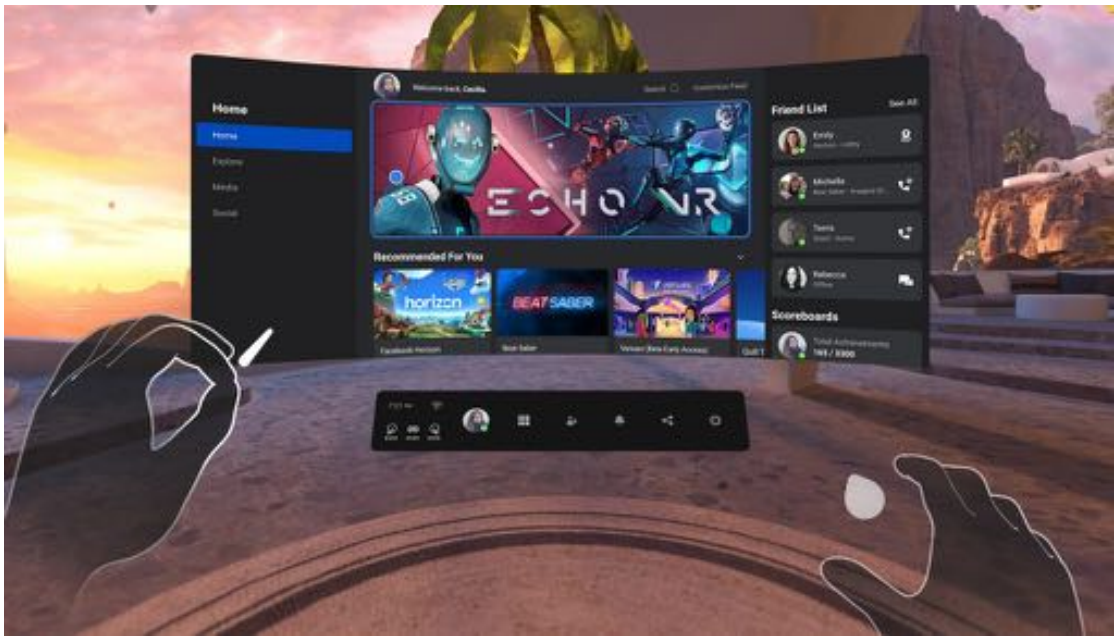

FIGURE 2.1: User present in a virtual world, interacting with the system menu with the use of hand gestures.

2.1.2 How VR technology works

The screen inside the headset displays two images side-by-side, one for each eye. These side-by-side images create a 3D stereoscopic image similar to how 3D movie glasses work. This illusion gives the user a sense of depth & presence, hence realism, as it replicates human's interpretation of reality. More advanced headsets contain a head tracking system that maps the screen image to where the user moves their head, mimicking how we see in real life[3]. User input is achieved by using controllers that are designed to be held by the user. However, more advanced headsets contain cameras on the outside that allow for user input to be detected with the use of hand gestures only (see Figure 2.1), which helps make the experience feel more natural.

2.1.3 The importance of researching VR technology

History shows that emerging new computer technologies have completely changed our lives and the course of humanity. Be it the first desktop computer that allowed us to store data electronically, the Internet that gave us access to instant information or artificial intelligence that has challenged our intellect in topics such as board games [4]. Now, the next phase of computing is potentially emerging, which may be powered by virtual & augmented reality [5].

One method to garner the importance of this technology is by simply looking at the investments and public statements that "Big Tech" have made in virtual reality technologies in recent times. Facebook, the parent company of the wildly popular Oculus VR headsets[6] have announced that they will be spending at least $10 billion this year on Facebook Reality Labs. Reality Labs is a subdivision of Facebook that research and produce its AR, and VR hardware [7]. Apple also has invested extensively in VR / AR technologies and plans to unveil their first mixed reality headset as early as 2022 [8], according to Bloomberg analyst Mark Gurman, who has a prediction accuracy score of 87% concerning apple hardware announcements [9]. Sony is also set to release the next version of their gaming VR headset, PSVR 2 [10]. These investments by Big Tech show the level of interest that the industry has in virtual reality technology and its potential. Even though the primary use cases for these headsets seem to focus on the gaming industry, remote work and collaboration seem to be getting an overhaul by introducing VR headsets into the workplace. A shift that Bill Gates, founder of Microsoft, stated in his annual "Year In Review" blog and believes will take place in the next 2-3 years [11].

2.2 State of the Art (VR in General)

To emphasise the importance of this technology, I initially sought out to gather and review papers that show the impact VR has had on industries to date. However, from my research, I have come to the conclusion that VR technology is still largely conceptual, so I have reviewed three papers below that show the promises/impacts that authors believe will happen to three select industries to convey the possible impact of this new technology. These three industries are sports, real estate and e-commerce. Finally, I have also included two papers that discuss the safety of VR technology and the current hurdles that it faces.

2.2.1 Virtual Reality and it's potential in the Sports Industry

The following is a review of "The impact of virtual reality (VR) technology on sport spectators' flow experience and satisfaction" [12], 2019.

The authors of this paper set out to conduct a study to determine if VR headsets could increase a user's telepresence for sports events. Virtual Reality Spectatorship (VRS) is an emerging medium for sports media consumption. The user experiences the thrill of being at a sporting event whilst in the comfort of their own home. The authors assume that VRS may receive mainstream adoption on the basis that it can deliver a much more optimal experience as opposed to today's means of sports consumption. The study

FIGURE 2.2: Picture of VR user attending a football match using Sky Worlds VR.

involved two groups, where one group consumed sports media through a VR headset and the other group experienced it through a 2-D screen. Their findings concluded by stating that "in the context of sports media consumption, VR technology significantly enhances telepresence through increased vividness and interactivity". Therefore, the users received an improved experience with the use of VRS.

This shows great potential for VR technology as if it comes to fruition, it will allow more spectators to visit (virtually) any stadium to watch a match, which in turn will provide incentive for the sports business as they will be able to sell more tickets than the stadium would otherwise allow. Also, in light of recent global events (COVID), another element is that VRS will provide sports with a more robust system for continuing sports events even if the stadium is closed to spectators with lockdown restrictions. So, even though demanding fans may not be able to attend an event in person, they will still have access to a platform that provides a more immersive and intimate viewing of the game. Sky has already begun implementing this idea with an app named Sky Worlds beta [13]. This app allows sky customers to view premier league matches as though they are actually at the game (see Figure: 2.2). A neat function of this app is that it allows more than one person to sit in the best seat at the stadium, resulting in all VR customers getting an optimal viewing experience. Further, it also allows viewers to change seats to get another angle on the game. Finally, by using VR, it will allow the user to experience features that would not be possible at an actual game. Note in figure 2.2, the user is watching a live view of the game in VR with the added benefit of seeing the replay of a goal on a gigantic screen that would not be feasible in real life. To conclude, it is clear that if implemented correctly, VRS may completely change the way in which we view sports in the future.

2.2.2 Virtual Reality and it's potential in the Real Estate Industry

The following is a review of "Matterport: Virtual Tour as A New Marketing Approach in Real Estate Business During Pandemic COVID-19"[14], 2020.

FIGURE 2.3: Picture of person attending house viewing using the Matterport platform

The authors of this paper conduct a case study to research the impact VR technology can have on real estate, more specifically house viewings. The authors define four categories to compare the conventional modes of house viewings, being in-person and 2D slideshows on a screen, to that of a new experimental model, virtual reality viewings. These four categories are accessibility, visual capture, details information and visual experience. The case in study is Matterport, an online 3D virtual viewing platform that allows homeowners to capture their home in 3D and upload for public viewing (see Figure 2.3). The authors conclude by saying that this new approach to real estate listings may help drive the decision making of buyers due to the hyper-realistic VR experience that it delivers.

The authors argue that the accessibility provided by VR viewings is greater than the compared means; however, I have to disagree as I believe that the convenience of using VR to view a property and viewing it on a laptop to be on par. Despite this, the main benefit that this technology provides is an experience that can accurately mimic an in-person viewing without a need to travel to the site. This results in a safer option for viewers looking to buy during a pandemic without sacrificing the benefits of in-person viewings, such as presence and determining a sense of the scale of the rooms. Note that it is still too early to deduce whether or not this technology will actually increase buyer decisions making. However, the reasoning provided by this paper is promising.

This paper is important to my research as it displays the beneficial features of VR in the real estate industry that would otherwise not be possible with a 2D screen, hence, increasing its importance as a technology.

2.2.3 Virtual Reality and it's potential in the E-Commerce Industry

The following is a review of "The influence of virtual reality in e-commerce"[15], 2019.

Another industry that stands to gain from VR technology is the world of e-commerce. Currently, the two ways of shopping consist of in-person stores and online web stores. Online shopping has clearly proven itself to be a mainstay in the world of commerce [16]. However, as effective as it is, the authors of this paper believe there can be more achieved when it comes to online sales, a new way of shopping, dubbed v-commerce.

The authors conducted a study to determine if the positive consumer responses that are invoked in physical retail stores could be replicated with the use of virtual reality headsets. That is to say, the benefits of in-person shopping could be merged with the benefits of online shopping. For the study, the authors created a virtual supermarket and exposed it to the volunteers. They noted that the simulation was a faithful recreation of a physical store in order to extract valid comparisons. The authors discussed that the virtual store was "more effective in generating cognitive and conative responses" in this study. They found that brand recognition recall was significantly higher when shopping through the virtual store instead of the physical store. If this result can be replicated in another study, it could prove to be a significant finding for the future of v-commerce. Suppose brand recall is higher for those who shop in v-commerce. In that case, it will incentivize brands to invest in this sector as it may make them more memorable to the shopper, which is an essential requirement for their marketing campaign [17].

The authors conclude that virtual stores could elicit purchase intentions through invoked emotion and the effect caused by brand recall. These results suggest that VR has great potential to impact this industry dramatically. This paper is important for my research as it confirms the potential value that VR has on another industry.

2.2.4 Virtual Reality and the Safety Aspect of it's Hardware

The following is a review of "Effects of Immersive Virtual Reality Headset Viewing on Young Children: Visuomotor Function, Postural Stability, and Motion Sickness"[18], 2020.

When looking at new technology and its ability for mainstream adoption, one factor that needs to be considered is the safety of this new technology. With virtual reality technology, as the screen is in close proximity to the user for an extended period, we need to evaluate if it produces any harmful effects on the eyes. The following is a paper which researches precisely that.

The authors conducted a study with 50 children aged 4 - 10, where they interacted with a VR experience for a total of 60 minutes each. They conducted an eye test preceding the headset exposure to look for any eye impairments and also their postural stability. The results concluded that 94% of the students that completed the VR sessions had no difference in measures from their initial baselines. The results also showed a degradation in postural stability of 9% on average after an hours use of the headset. The authors concluded that there were no noteworthy negative effects on visuomotor functions when using a VR headset, nor did the experience create a significant postural insatiability. This research paper is important for both my own studies and for VR as a technology. It is important for my study as it shows that there should be no visual issues with students from partaking in my research. It is also important for VR in general as it shows no early signs of issues with the use of the technology. I will note, however, that this trial did not cover any long-term effects as the experience only lasted 1 hour. Further research will be needed in order to determine if there are any effects due to long-term exposure.

2.2.5 Virtual Reality and the Current Challenges it Faces

The following is a review of "Toward Interconnected Virtual Reality: Opportunities, Challenges, and Enablers"[19], 2017.

Even though there are many opportunities for virtual reality, there still exists many hurdles that the technology has to overcome in order to get reach a wider adoption. The authors of this paper evaluate and discuss the technological challenges that virtual reality faces in order to become a break-out technology, that is to say, become mainstream. They state that "the overarching goal of VR is to generate a real-time digital experience that mimics the full resolution of human perception." The VR displays would need resolutions higher than 8K in order to accommodate this, which is a resolution that is not financially viable with today's technology, as the product would become too expensive for most people, which brings us to our next point, media. Even if we had VR headsets that satisfied our visual resolution needs, the applications, more specifically the media, would need to then be rendered in this resolution, which would be both computationally expensive and require much larger bandwidths to prevent buffering. "Immersive

technology will require massive improvements in terms of bandwidth, latency, and reliability." Here I have only cited two challenges, yet there exist many more. For example, the 3D effect of the headsets needs improvement, the field-of-view needs to be wider to match our own peripheral vision, and the weight of the headsets need to be dramatically reduced to allow for extended use. So even though VR is becoming more widely used in different industries, it is still severely limited in capabilities that prevent it from achieving the realistic experience that users desire. However, all of these challenges mentioned above are technological in nature, and we are slowly iterating on them one at a time.

2.3 State of the Art (VR in Education)

Now that we have a general sense of what VR is and its potential impacts on the world, its not time to research how it can be beneficial to the industry of education. The following section details eight papers on VR with respect to education. The objective here is to see what has already been researched and to learn from their insights to aid in my developing of an educational application.

2.3.1 Virtual Reality and it's potential impact on Science in Education

The following is a review of "Learning Science in Immersive Virtual Reality"[20], 2018.

This paper details a comparison between learning indicative education content through the use of Virtual Reality and traditional means. The authors prepared a unit of study in a PowerPoint slideshow and in VR. Students went through the content of these units and a retention test was conducted afterwards. They also conducted a qualitative analysis where students gave feedback on the lesson. The study concluded that the students scored significantly better using the slideshow as opposed to the VR headset. It was also noted that the students spent less time with the slideshow than the VR lesson, showing that the slideshow was better for retention and more efficient. However, the qualitative feedback showed that students who used the VR application felt significantly more engaged in the experience. They also reported much higher levels of happiness, excitement and motivation. Students that completed the VR lesson also pointed out that they felt distracted by the excitement of the experience which caused them to be less focused on learning the content. The author notes that the VR lesson had many moving visuals which may have hindered the students focus on the narration of the learning content. This paper is useful to my research as it agrees with my hypothesis that VR lessons can increase engagement. It also confirms my hypothesis that VR can overwhelm students and in turn, possibly decrease retention. I can apply these findings

to my project by only implementing objects that I believe will aid the student in learning as opposed to distracting them from the lesson. This paper however, does not confirm nor deny if long term exposure to VR will have a reduction in distraction effect as the users become more accustomed to the VR experience.

2.3.2 Virtual Reality and it's potential impact on Linguistics in Education

The following is a review of "The Effects of Virtual Reality Learning Environment on Student Cognitive and Linguistic Development"[21], 2016.

The authors of this research paper conducted a study to convey the advantages of learning indicative content at third level education with the help of virtual reality. The subject taught was foreign languages (English) to non-English speaking students. The authors created a virtual environment with 3D avatars that spoke and the student had to pick the right answer, with the hope that the contextual learning would aid students. The methodology included game based learning where the students completed scenarios that would take place in one's daily life. The ability of the students to speak English was testing before the VR learning experience and then again after they had completed the learning experience. The results showed a significant increase in the post-test, suggesting that the students had increased their phonology, vocabulary and grammar with the aid of the VR lesson. The authors noted that ease of use, clear instructions and ease of operation of the application was influential in the success of this VR lesson. I can use this insight to be more thoughtful when designing the menu / navigation of my application. This paper is beneficial to my research as it highlights the importance of ease-of-use in aiding a student in learning.

2.3.3 Virtual Reality and it's potential impact on Work Training

The following is a review of "Promoting Knowledge Construction: A Model for Using Virtual Reality Interaction to Enhance Learning"[22], 2018.

This paper accesses perceived performance of a group of college students building a PC in Virtual Reality. Each student is given the task of building a PC from scratch through the use of interactive controllers and a VR headset. At the end, the students answer a questionnaire that is used to gain information on usability and the emotion states of the student. The results showed that the students found the experience engaging, interesting and they also reported high levels of perceived knowledge gain. This paper is not necessary something that can be applied to my research as students were not tested

on learning indicative content. However the results do show an interesting thought. The authors report that there was no difference in performance between the students building a PC in VR and the control group building a PC without VR. If this is the case then training workers in VR to perform physical tasks, like building a PC, could be beneficial to them in completing the task in real life.

2.3.4 A review of "Learning in virtual reality: Effects on performance, emotion and engagement, 2018"

The following is a review of "Learning in virtual reality: Effects on performance, emotion and engagement, 2018"[23].

This paper is similar to paper 1 as it investigates the same level of students by testing them in the same field of study, biology. However, the authors of this paper also include video lessons as a means of study. The qualitative analysis shows similar results to paper one, in that students seem to prefer VR as a medium over traditional means (textbook). Interestingly, the students scored video pretty similar to textbook, high negative feedback and low positive feedback. The reason I have included a paper similar to paper 1 is due to the findings that this paper found with the quantitative analysis. The quantitative analysis was conducted, by first, having students complete a biology test in order to gauge their level of comprehension on the subject before providing the lesson. They then compared the post-test results with these pre-test results and their findings were fascinating. Students who did the VR lesson showed a 28.5% increase in knowledge, Video a 16% increase and textbook a 24.9% increase. Therefore showing that, in this experiment, VR had the greatest impact on retention. These findings conflict the results found in paper 1. There are many reasons as to why this could be the case. First, paper 1 did not conduct a pre-test in order to gauge initial comprehension, so the students of the PowerPoint group may have had a better grasp of biology, resulting in higher markings. Second, paper 1 reported students becoming distracted by the environment of the VR lesson and finding it harder to focus on the narration. This paper did not report such findings so the design of the virtual environment may have been less distracting to the student, therefore allowing greater focus. Third, this VR lesson did not have narration, instead students read text in VR so this variable may have also played a role in the difference of results. Lastly the authors may have took different pedagogical approaches lesson. Despite this, this paper is beneficial to my research as I believe the methodology they carried out for the test is more robust and I will implement a similar methodology when designing my assessment. Overall this paper shows that VR education may have real potential as not only did the medium perform better for retention, it also showed a greater increase in engagement as reported by the quantitative analysis.

2.3.5 A review of "Exploring Effects of Interactivity on Learning with Interactive Storytelling in Immersive Virtual Reality, 2019"

The following is a review of "Exploring Effects of Interactivity on Learning with Interactive Storytelling in Immersive Virtual Reality"[24], 2019.

This authors of this paper conducted a study to research if the level of interactivity provided to the user of a VR educational app had an impact on their retention. The study was conducted on a group of college students and the subject of choice was immunology. The authors created three educational apps, with the same educational content. However, each application had a different level of interactivity. The level of interactivity was classed as low, medium & high. Low interactivity had the application automate every task apart from head movement, high had the students interact with the application as much as possible and medium was an even level of user-interaction and system automation. The hypothesis' are

1. Interactivity will significantly affect the students learning retention
2. A medium level of interactivity would produce the greatest gains
3. Increased levels of interactivity will increase user engagement overall.

The results show interesting conclusions, the authors did not find evidence from the objective data (quantitative test results) to support the hypothesis that the levels interactivity would influence student retention rates. This goes against my own presumptions as I believed that a hands on (interactive) experience would positively impact learning outcomes as it does so in traditional education such as practical lab sessions. However, the authors do note some limitations to this study which may have influenced the results. They state that their sample size may have been too small to quantify significant results (20 people per interaction level). They also state that regards the high level application, students found the virtual movement hard to control and ended up feeling disorientated. So this distracted the users from the lesson. The authors did conclude that the subjective data supported hypothesis three. This paper is beneficial to my research as it seems to show that interactivity may not help students with learning outcomes. However my personal opinion on the study is that I do have my reservations on their findings due to the positive impact that interactive (practical) labs have on students at third level education.

2.3.6 A review of "Virtual Reality for Early Education: A Study", 2016

The following is a review of "Virtual Reality for Early Education: A Study"[25], 2016.

The authors of this paper conduct a study to see if virtual reality can aid students in learning history. The group for the study consisted of students from secondary school level. To gather data, a qualitative and quantitative study was conducted by means of a questionnaire and observation. The experience consisted of a 3D model of St Andrews Cathedral in Scotland, where students could enter and learn about its history for 10 minutes. The control group experienced this app through a computer screen. The hypothesis was that the virtual reality headset would stimulate more interest & provide more immersion in learning history than a computer screen. The results confirmed that virtual reality does in fact stimulate more interest in learning history through a VR headset medium. The study however, found no statistical difference to prove that VR could provide more immersion to the user than a computer screen. The authors concluded that this could be due to the fact that the experience did not allow free movement within the cathedral. The students were limited to fixed points within the app and argued that this feature may have broken the immersion factor of VR. This paper is not necessarily important to my research however, there are two takeaways that may be of benefit. As the authors stated that free-roam capabilities may lead to more immersion, I might implement this feature in my own research. One issue that did stand out however, the eye-level at which the students experienced the app was set to the height of an average male, which is higher than the eye-level of the young students. As a result, the students expressed perceived dissonance when using the app. The authors concluded that this may have hampered immersion so as a result, it may be of benefit for me to implement a feature where the student can adjust the height to enhance realism and not break immersion.

2.3.7 A review of "ClinicaVR: Classroom-CPT:A virtual reality tool for assessing attention and inhibition in children and adolescents, 2016"

The following is a review of "ClinicaVR: Classroom-CPT:A virtual reality tool for assessing attention and inhibition in children and adolescents"[26], 2016.

This study of this paper is for assessing whether or not virtual reality can be used as a tool to gauge student attention during a lesson. Initially I thought this paper sought out to see if virtual reality caused a distraction in users and to assess what those

distractions were. I believed that I could use that knowledge to further mitigate any potential distractions in my experience. However, this paper serves a different purpose. The authors replicated a real-life classroom in VR that include audio/visual distractions that occur in the daily life of a student. For example, moving objects outside of the classroom window. The goal of the authors was to see if VR could help identify students that get distracted easily in the classroom and to what degree. This paper is not relevant to my research however they did report findings that may be relevant to VR in education in the future. The results showed that 57% of students experienced fatigue, 30% experienced headaches & 67% experienced eye strain. To access whether VR can serve as a valuable tool for formal education, we also need to look at the safety of the hardware. These headsets needs to be free from impediments that may hamper the learning experience but also not pose any long-term health issues. These findings show that virtual-reality technology may have some hurdles to overcome in order to become a safe tool in formal education.

2.3.8 A review of Virtual Reality as a Learning Tool: How and Where to Start with Immersive Teaching, 2019"

The following is a review of "Virtual Reality as a Learning Tool: How and Where to Start with Immersive Teaching"[27], 2019.

This literature review was conducted to get feedback from teachers who tried virtual reality technology in a formal educational setting. The authors found 6 teachers who applied this technology to their education stack. The teacher's length of teaching ranged from 3-28 years and they taught subjects Geography, Maths & Chemistry. They have been implementing VR into their teaching for 6 months – 4 years. Their finding show that VR could be useful in an educational format provided that there was a suitable pedagogical approach followed in the designing of the lesson. The pedagogical approach that they suggested other teachers to start with is constructivism. This paper is useful to me as it has identified a pedagogical approach, that is backed by educators who tested VR in education, that I can adhere to when designing the lesson.

2.4 State of the Art (VR Framework technology)

From researching these various papers, a common trend began to unfold. Of the papers that spoke about the technology used to implement their experience, 5 papers utilised third-party game engine technology, the Unity3D engine to be specific. From this finding it is safe to assume that the use of a third-party game engine has been a popular

technology in order to conduct these studies. This finding is important to my research as it presents me with a framework I can use in my own development of my education app. Even though these papers listed the same engine, there are actually two main game engines in use these days by companies, the other being Unreal Engine (UE) by Epic games. I have decided to include one paper that compares both technologies, in order to gain extra information as to which would be better suited to my own project if I were to utilise said technology.

The following is a review of " Comparison of Unity and Unreal Engine" [28], 2017.

The author of this study conducted a comparative between the two most popular game engines used in the gaming industry. For this study, the author created a 3D Pac-Man game in both engines and compared each engine on ease-of-use, features, quality of official documentation and performance of the engine. The authors findings show that when using Unreal Engine on a mobile device, which is similar to the VR headset I will use, it has much higher performance than Unity. He also found that Unreal Engine has a better particle system, better shader system, more cinematic tools and the ability to generate much more true-to-life terrain and foliage than Unity. On the surface, this seems like an ideal choice as it conveys the thought on Unreal engine being a more optimised framework for mobile app development, however, the author has an interesting opinion on which engine to use.

The author found that learning the Unity framework as a much simpler task than Unreal's framework. He states that the architecture is simple to understand, the documentation is well written and the community is vast, a place where many developers share tips on implementation. He says that even though the Unreal Engine is much more powerful, it is slower to develop for and more focused towards larger projects with bigger Dev teams as opposed to solo developers, which is my situation.

This paper is important to me as it conveys many reasons as to why the researchers in the papers I reviewed chose the Unity engine. Of all the papers reviewed, not one researcher mentioned the use of Unreal Engine in their study. This brings me to the conclusion that the Unity Engine is a better choice than Unreal for my specific project as it tailors more to my needs as a solo developer.

Note that I could not find a suitable comparative between these two frameworks with respect to VR development specifically. However, the fact that so many researchers chose Unity over Unreal signals to me that the Unity engine translates well to VR development.

2.5 Education Student Engagement

Prior to undertaking this research project, I had little understanding of the factors that influence student engagement or the measurements that are used to gauge student engagement in higher education. Therefore, I have included the following paper to aid in my understanding of said topic.

The following is a review of "The Challenges of Defining and Measuring Student Engagement in Science" [29], 2015.

In this paper the authors discuss the various challenges of measuring student engagement and propose a solution to tackle this problem. These challenges include: not defining in advance which types of engagement a researcher wants to analyse, not taking into account individual differences that result in making a comparative more difficult & using only a single method of measure as opposed to many. The authors conclude that as it is difficult to pinpoint the source of engagement due to the different types of engagement overlapping, it is better to measure engagement on a continuum (See Figure 2.4). They state that this allows the researcher to consider each mode of engagement. For example, if deciding to research at the far end of the continuum (Peron-Oriented), the researcher need not be worried on deciding which engagement type to focus on as they will be focusing on all of them.

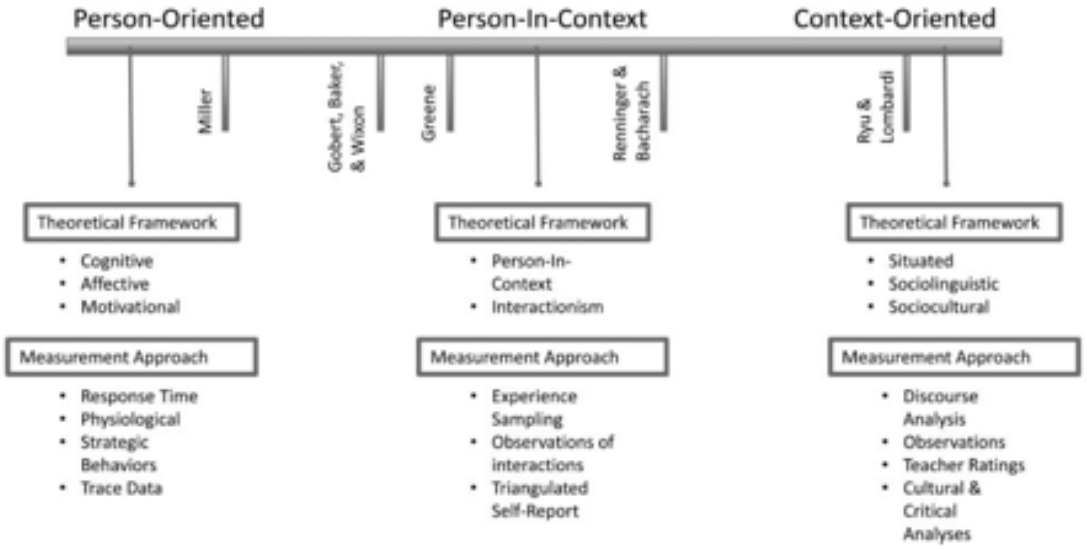

FIGURE 2.4: Picture of continuum of engagement measurement.

As this paper is outside the scope of my usual studies, it was a slightly above my level of comprehension. However, it did highlight some details about engagement that I can utilise when developing my assessment. This paper was aided in my understanding of student engagement as it made me aware of the different types of engagement, those

being: behavioural, emotional and cognitive engagement. Therefore, this research paper is important to my study as I will now design my assessment to include questions that account for the different types of engagement, and therefore, come to more insightful conclusions.

Chapter 3

Problem - Can we increase student engagement through the use of virtual reality technology?

3.1 Problem Definition

The upward trajectory of VR growth suggests that it may become more and more ubiquitous in our lives [30]. As more and more companies begin to push their own version of virtual reality technology we can see the potential positive impact the hardware is starting to have on many different industries [31]. One industry that can potentially gain from this technology is education. Learning through VR can provide many benefits. Just to name a few, these are:

- **A more robust system**: If we were to conduct learning from our own home through VR, it would provide a more robust system in response to worldwide events such as pandemics and other disrupting future events.
- **Inclusivity**: We would no longer be tied down by our physical location in order to attend lectures, instead, anyone with a headset could participate irrespective of where they live.
- **Connection**: Instead of conversing with peers through a 2D laptop screen over zoom, we could interact with each other in a 3D spatial environment, simulating a real world classroom. The result of this would be in a greater sense of presence and personal connection.

- **Asynchronous Learning**: Students can complete the module units in their own time instead of being constrained to attending lectures during designated hours of the day. By allowing students to learn units in their own time, it gives them the flexibility to design a study plan that caters to their different learning styles. This mode of teaching also offers flexibility as students can go at their own pace and repeat the unit of study if needs be.

For this project, we will solely be looking at engagement with respect to academic content, so this project pertains to engagement of students in a formal education setting. To do, we will research to see the applicability of VR to function as a suitable medium to deliver practical work in formal education. Formal education has two objectives, these are:

1. To teach indicative content
2. To assess indicative content

Objective (1) is achieved through the use of lectures and labs. Lecturers generally teach theory during lectures and assign practical work during labs. Objective (2) is achieved through the assessment of assignments and/or exams. So, in order for us to assess whether or not VR can help students learn, we have three research questions to be answered. These questions are:

1. Can lecturers actually teach indicative content in VR?
2. Can lecturers actually assess indicative content in VR?
3. Are students actually engaging with the learning material?

Question (1), (2) and (3) can be addressed via an experiment that will compare the engagement level of students studying the conventional method and students studying through the use of VR technology.

3.2 Objectives

The following are the objectives I plan to achieve:

- Decide on a suitable pedagogical approach.

- Compare and contrast different methodologies in order to try and find a universal methodology that can be followed as a roadmap when developing other indicative content for different topics.
- Using a game engine, design one unit, of one particular subject, at a certain educational level, as a VR educational app to provide a learning experience for the student.
- Design a quiz to conduct a quantitative study to test the participant's retention rates.
- Design a second quiz to conduct a qualitative study, where participants rate their experience, in order to measure user engagement.
- Design a database to store participants data as well as the quiz data (if the quiz takes place inside the VR headset).

3.3 Functional Requirements

- When the student touches an object, it should react in real time.
- When the app starts, a settings screen should pop up in order to adjust gameplay options.
- When the student launches the app, they need to be able to create a profile and login.
- Student login data and tests result data should be stored in a database.
- Specify a methodology to design the education unit.
- Create one unit of indicative content for the student to complete.
- Create a dialogue in order for the unit to be taught.

3.4 Non-Functional Requirements

- **Accessibility**: The educational content needs to be able to be experienced while seated in order to adhere to accessibility.
- **Motion sickness**: Students should have the option to pan freely or pan in locked degrees to accommodate for potential motion sickness.

- **Usability**: The interface should be easy to navigate as VR may be entirely new to them.
- **Performance**: The experience needs to be consistent throughout the experience to not drop any frames or freeze the app.
- The sample size of the groups should be big enough in order to draw reliable conclusions.

Chapter 4

Implementation Approach

4.1 Architecture

The main technology/framework that I plan to use to develop this experience is a game engine. Building VR applications for the Oculus Quest platform is a complex attainment. Oculus provides the ability to do so with the use of native development for the platform. As the VR headset runs on android, the native route involves using Android Studio with the Oculus Mobile SDK. The Oculus Mobile SDK being a kit for libraries, tools and resources for native C/C++ development [32]. However, this method requires the experience of a seasoned developer as it lacks many functionality that other frameworks offer. Therefore, I have decided to build this application with a game engine. Also from my research in Chapter 2 (see section 2.4) , the vast majority of studies utilised a third-party game engine.

A game engine is a software development framework with settings and configurations that optimize and simplify the development of video games [33]. When building an educational app in VR it can be thought of as building a game, utilising the game engine to streamline the process with pre-built assets and functions. As already discovered in Chapter 2 (see section 2.4), the two main game engines are Unreal Engine by Epic Games & Unity3D engine by Unity technology. Both of these game engines are supported by the Oculus Quest platform. From my research on game engines in chapter 2 (see section 2.4), the engine I plan to use is Unity3D. As well as the reasons stated in chapter 2, another reason for the Unity engine is that it uses C# where as Unreal uses C++, a language that will take much more time to learn. Also from researching both engines, Unity is the preferred option for beginners as it has a more intuitive UI [34]. I have zero prior experience with VR development so I am very conscious with choosing a technology that will allow me to be more productive and succeed in this module. By using a game

engine it will free up resources to allow for a greater focus on, the logic of each asset in the unit of study, the design of the environment to maximise student engagement and the design of the in-app menus. As a result of this streamlined pipeline, this will allow for more iterations of the application to improve on its performance and feature set. Finally, unity3d is a platform agnostic engine, therefore allowing me to cross-compile this app for hardware other than the Oculus Quest 2 if I choose to do so in the future.

4.1.1 Unity IDE

FIGURE 4.1: A picture of the Unity Game Engine IDE

The Unity environment is the IDE I will use to construct my application 4.1. It differs from the IDE's I have used in the past as it includes pre-built assets & a graphical view of the application I will be implementing. As unity uses C# (wrapped over C++) the format for this language is object oriented programming. Section B of the above image is a hierarchical window which consists of all the objects (game objects) being used in the scene. Section C is the game view. This window simulates in 3D, however the final render of the application will look like to the user. Section D is a window that mimics the game view objects in polygon form, allowing for scene editing and a visual navigation of the environment. Section E is the inspector window, this view allows me to edit the properties of game objects. Here I will define the logic for the assets I will be using in my educational experience. The logic will be defined using C# scripting.

4.1.2 Physics Engine

Unity also incorporates a physics engine. This engine will allow me to realistically simulate object interactions and respond to collisions and forces like gravity. This will result in a unit of study that is more in-tune with the real world and provide a more applicable teaching lesson.

4.1.3 XR Plugin Framework

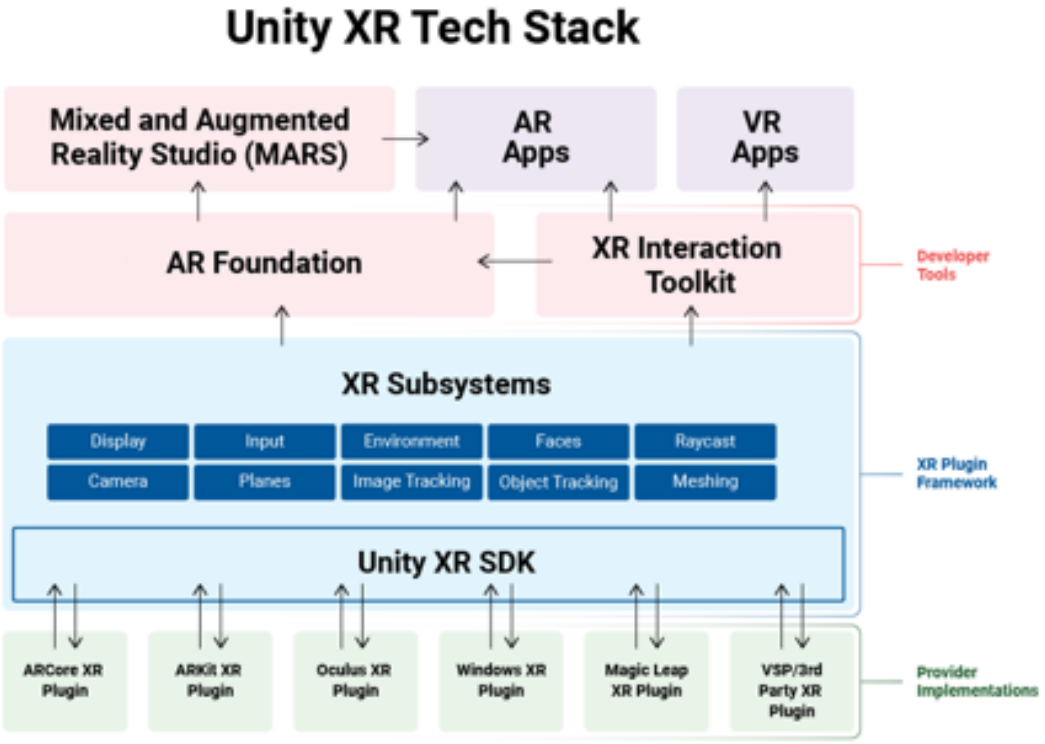

FIGURE 4.2: A picture of the Unity Game Engine's XR Plugin

Unity utilises many plug-ins 4.2 to improve on the versatility of this technology. In order to build for VR applications, Unity have developed an XR plugin framework. This framework enables VR developers, like Oculus, to integrate this engine with the use of an API. This API allows the native features of VR, like motion input, haptics & body positional tracking to be mapped correctly to the application developed with unity.

4.2 Risk Assessment

Below are various risks & challenges that I have identified so far with the implementation stage of my project.

4.2.1 Risk 1: Inability to carry out survey

- Consequence – Critical
- Chance of occurring: Probable

Currently MTU's plan for semester 2 is to have students back on campus. However, with keeping in line with COVID guidelines as set out by the government and with the current trend of COVID cases, online learning may be extended, even to the point of halting a return to campus for semester 2 altogether. As a result, this may prevent me from conducting the survey as I will not be in a position to be on-site to deliver the unit of study with the VR headset.

A proposed solution that I have is to, instead of conducting the survey in person, deploy the application to the Oculus store using App Lab. This will enable me to conduct the study online and gather volunteers by reaching out to various VR communities such as discussion website, Reddit.

An advantage to this approach is first, the size of the community (300,000 users) and second, most if not all of these users have their own headsets, so all they need is to download the application and complete the lesson.

If this means is required, a few changes will need to be made in order to accommodate this approach and to keep integrity of the survey. First, to keep integrity of the questionnaire, I believe implementing it inside of the actual headset will first, increase the number of users who complete it and second reduce the ability

By conducting both the pre-test and post-test inside of the application, my assumption is that this more seamless & frictionless experience will result in more users completing the actual test. It will also increase the integrity of the test as users will be less inclined to google any answers.

Note that this method of gathering data for my analysis may render it less-likely for me to gather a control group, that utilise the PowerPoint lesson, as it may be harder to gather a control due to lack of interest in listening to a PowerPoint presentation than trying something new in a VR device. However, because of the pre-test and post-test

conducted, it will still allow for me to draw conclusions on Question 3 noted in chapter 3.

4.2.2 Risk 2: App not optimised to a playable state

- Consequence – Major
- Chance of occurring: Occasional

Getting the app to run at a consistent frame-rate of 90 frames-per-second is a fundamental requirement in order for the user to have a positive experience with the lesson [35], this can be seen in other games where the frame drops and it causes a lagging effect on the game. I have no experience in optimizing games to hold a consistent frame-rate so this may prove to be more challenging than expected. An application with poor performance can have a negative impact on user experience which will likely skew the results and lead to more negative feedback that is related to performance as opposed to the indicative content. As this headset is stand-alone, it uses a less powerful mobile processor and GPU, therefore I do not have the extra power that a PC would supply in order to compensate for any unoptimized code I implement.

A solution to this is to build the application with performance in mind from the beginning and try to always target a smooth frame-rate of 90FPS. Also Oculus has various articles on optimization so I will utilise these resources before I begin to build the application.

4.2.3 Risk 3: Ineffectively managing my time resulting in incomplete project

- Consequence – Critical
- Chance of occurring: Remote

With this project I will be using technologies that I have no prior experience in. I have not built an application for VR before or used the unity game engine. As a result it is difficult to quantify the amount of time it will take to build this VR app, also, it is highly likely that features I plan to include may take longer to implement than originally thought which may result in the app being unfinished and possibly unplayable if said features are fundamental.

It is very important for me to put a greater emphasis of time on building the fundamental parts to this application that allow for a lesson to take place. In order to keep on track

with building this app I will set weekly goals that will consists of learning, implementing and testing the components that make up this project. I will take the approach of developing a minimum viable product (MVP) and iterate over its design and features. This will ensure that I have a working product for when I conduct my comparative study. I will also need time to find participants and make conclusions based on the data I receive. As a result, I will need to have the application ready in advance of term ending to account for these steps.

TABLE 4.1: Initial risk matrix

Frequency/ Consequence	**1-Rare**	**2-Remote**	**3-Occasional**	**4-Probable**	**5-Frequent**
4-Fatal					
3-Critical		3		1	
2-Major			2		
1-Minor					

4.3 Methodology

This section details the approaches I have taken and plan to take for the different stages of the project, including: Research, Learning & Project Management.

4.3.1 Research

There are three main components that make up this project. These are, the application implementation, survey and the pedagogical design of the lesson.

For the survey, I have researched the methodologies carried out in various different studies in chapter 2, and will utilise many of the practises they put into place to conduct their research.

Similar to the survey, I have also done research in the field of teaching to help me determine the appropriate pedagogical approach to take when designing the lesson.

4.3.2 Learning

A significant amount of learning will be required to understand the technical requirements of this project for the implementation phase. I will need to understand the components of the unity engine, the C# language, scripting, how to handle Quest 2

user controller input & application optimisation. To gain these skill-sets, I plan to use the official documentation provided by Oculus and Unity. I plan to also utilise Udemy courses on unity fundamentals. Even though the official documentation provides a vast amount of information, I have had great success in the past with learning course content efficiently with the help of online courses. I will also make use of the official forums to contact other developers and get help on specific issues that I may encounter.

To understand the practice of teaching, I will have to learn more about the various types of pedagogy and which ones are more suitable to my means of teaching indicative content.

I have reviewed research papers from teachers, who are in a similar position, in order to decide on the best approach to take, however this may change if I discover another methodology that is more applicable to my project.

4.3.3 Project Management

As I plan to undertake an iterative approach for the implementation phase, I will utilise scrum and strive to complete as many features as possible over multiple sprints. At the end of each sprint I will hope to have a minimum viable product. As MTU plans to be back on campus for semester 2, sprints will allow me to gain feedback on the MVP from students to see if features, such as menu design, are easy to navigate and understand. This will allow me to further refine my product for student needs. I will keep track of my progress, such as features implemented, features planned and deadline using a Trello board.

4.4 Implementation Plan Schedule

- **Week 1 & 2**
  - Gather resources required to understand the game engine and C# language for scripting
  - Built prototype (skeleton) of game, i.e. app consisting of minimal assets and ability to interact with these in VR. Test performance
  - Implement behaviour in assets to test scripting functionality
- **Week 3 & 4**
  - Learn about implementing narration into application
  - Add more assets to game in order for a complete unit of study to take place

  - Design game to adhere for selected pedagogy
  - Add environment (background to game)
  - Get feedback on app performance

- **Week 5**
  - Add menu into game and features that adhere to accessibility
  - Get user feedback on UI design
  - Iterate over design if necessary

- **Week 6**
  - Set up SQL database.
  - Connect app to database and test connection.

- **Week 7 & 8**
  - Design assessment to be conducted.
  - Implement assessment into game.
  - Test thoroughly all aspects of game: design, menu UI, features

- **Week 9**
  - Create PowerPoint presentation of the same unit of study.

- **Week 10 & 11**
  - Gather volunteers & conduct study.

- **Week 12**
  - Use data gathered to conduct an analysis and derive insights.

4.5 Evaluation

To evaluate the success of this research project, it will be determined on the basis of the following points:

- Was a minimum viable product developed?
- Of the proposed functional requirements, how many were implemented successfully?

- To what degree (if any) has the ability to teach indicative content in VR being demonstrated?
- To what degree (if any) has the ability to assess indicative content in VR being demonstrated?

In order to determine the level of success achieved during this project, one needs to evaluate how many of the functional requirements were met that were set out in chapter 3. As these functional requirements are the basis for a fully operational study, any missing features will result in either the application having less significance or the quiz being less informative than required.

The main objective of this research paper is to determine whether of not VR can be used as a suitable medium to deliver indicative content at higher education. Even if this project succeeds in showing that students are more engaged with VR content, we need to look at the feasibility of implementing such technology into the formal education institute. We need to ask questions such as; How easy is it to implement an environment complete with indicative content? How fast can these applications be iterated on to adapt to different learning environments?

In other words, we need to quantify the ability of this project to scale upwards to meet the demands of different subjects.

4.6 Prototype

Below is a mock-up of a proposed solution to the design of the application. This design may change during the implementation phase if I discover a more effective way at designing the unit of study.

The below figure 4.3 displays a background, which will encapsulate the student in order to provide them with a more immersive experience. This background must remain subtle enough as to not distract the user but also allow them to feel more present in the topic of study.

The objects are different types of assets that the user can interact with using the touch controllers. This interaction is to provide a more active learning lesson.

As well as narration, the user will need easy-to-read bubbles to accommodate those who prefer reading over audio learning.

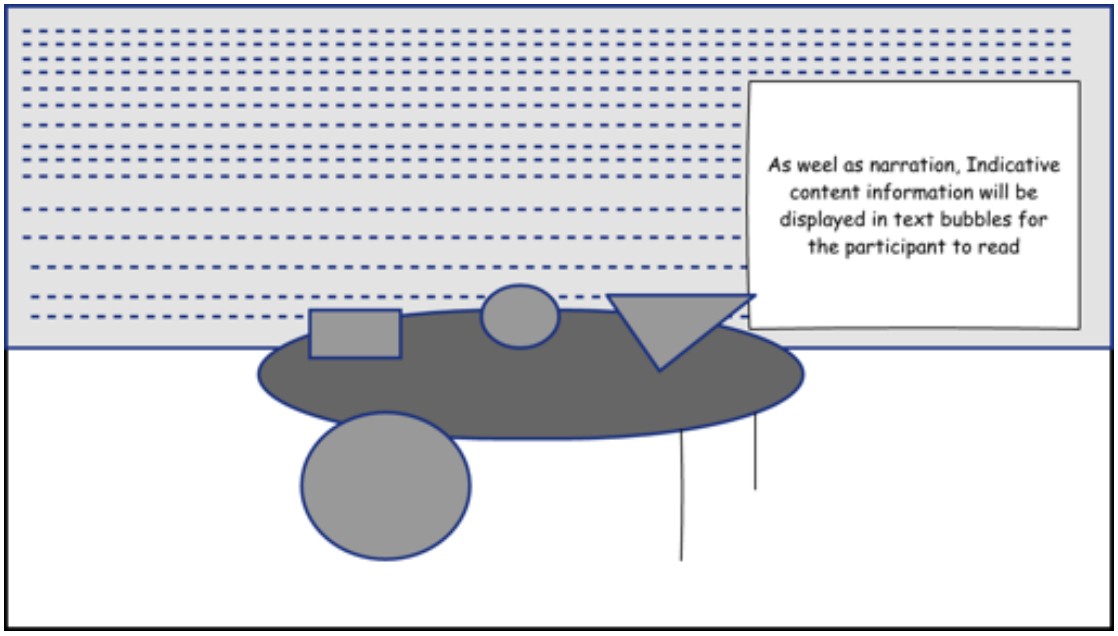

FIGURE 4.3: Prototype of App environment

Chapter 5

Implementation

This chapter should comprise 15 pages and enumerate your experience when doing what you wanted to do the way you wanted to do it.

5.1 Difficulties Encountered

Enumerate the different difficulties you have found when developing your solution approach. Create three categories of difficulties:

- **Easy**: You managed to solve the problem with little difficulty.
- **Medium**: It was not easy to solve, but you managed to develop a workaround or solution and still achieve the functionality you originally had in mind.
- **Hard**: The difficulty was so complicated that you didn't managed to solve it. As a result, some functional requirement / non-functional requirement or use case from your solution approach was not achieved.

For each difficulty, classify it into easy, medium or hard. Then, provide the following info:

1. Description of the difficulty: Brief description of the problem you found.
2. How did it affect the original project design?: Indicate how this difficulty affected:
   (a) the architecture of your solution
   (b) if it represented a risk to your project
   (c) if it affected your methodology to develop your project

(d) if it changed your implementation schedule

(e) if it changed the evaluation plan

(f) What did you do to manage the difficulty arisen?: Brief description of your decision to overcome the difficulty.

This section comprises of the choice subject for teaching and my reasoning, the actual solution approach undertaken to complete this project, and the various challenges encountered throughout the implementation.

5.2 Subject Choice

For the selection of the indicative content I set a few requirements, as follows:

As this project is about teaching indicative content to students, I sought out to choose a subject that is actually taught at a university level. Also, as this project is about the suitability of VR to teach said indicative content, I set the task of choosing a subject that highlights the novel and unique features of this technology. Those novel features being the ability for users to participate in experiences that would otherwise be deemed impossible, such as a trip to space, with a level of immersion and interaction not replicable by standard mediums such as video. As a result, I choose to implement a lesson from the field of astrophysics. For the topic of study within astrophysics, I set the task of choosing something that gives reason for users to take a trip to space in order to learn. The topic I chose is to teach students the equation of Newton's Universal Law of Gravitational, which is the law that governs how the planets in our solar system orbit the sun. I believe this is a suitable lesson for VR as it highlights the unique features spoken of above.

5.3 Actual Solution Approach

The lesson is split into two scenes, scene one is where the student learns about the theory behind this law and scene two is where the student puts the theory learned into practice.

5.3.1 Scene 1

The development steps of scene one were to implement:

1. Atmosphere/Environment

2. Narration

3. Animation

5.3.1.1 Atmosphere

I used the unity asset store and sketchfab to source different game objects that I could bring together in order to create an atmosphere and environment that feels realistic to the user. Initially, I sought out to render my own game assets, however upon realising how long it takes to design game objects and create individual materials, and the fact that the focus of this project is not on creating game assets, I decided that for the high fidelity objects (see Figures 5.1, 5.2, 5.3, 5.4), sourcing them was a better utilisation of my time. For the assets of a more simpler design, I created them myself from scratch. I then created the terrain and populated it with these assets by adding them to the scene in Unity editor, resizing them to realistic sizes and placing them throughout the scene with the x,y,z co-ordinates.

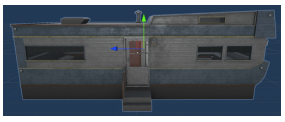

FIGURE 5.1: Van Game asset.

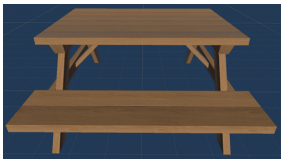

FIGURE 5.2: Table Game asset.

FIGURE 5.3: Tree game asset.

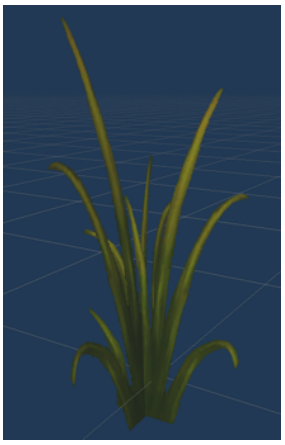

FIGURE 5.4: Grass game asset.

5.3.1.2 Challenge

From trying out and looking at other educational applications in preparation for this project, they lacked a sense of realism and felt unwelcoming as the user is present in a void of blue and grey. For my project, I wanted to prevent the user from feeling present in an environment that was uninspiring (see Figure 5.5), by developing a realistic one. However, from my findings during the research stage [2.3.1], I found that by including objects not relevant to the lesson, it could cause distraction among the participants as they want to look around and inspect the world. In that study, the author conveyed also that by including irrelevant dynamic objects, it increased further the level of distraction from the study. To overcome the issue of a uninviting environment (see Figure 5.5), whilst also preventing participant distraction from a busy environment (see Figure 5.6), I came to a middle ground solution (see Figure 5.7). First, I made sure that all dynamic objects were part of the lesson and not the surrounding environment. Second, and more importantly, to reduce the users want to look around whilst also creating an atmosphere that feels realistic, I reduced the lighting of the environment to mimic night and put lighting directly on the area of the lesson. By darkening the surrounding area and brighten the lesson area, this naturally drew the focus of the user to the area of importance whilst also reducing chance of the being distracted by the surrounding area.

5.3.1.3 Animation

The lesson consists of many animations in order to show the user the law of newton in action ref pic, ref pic. By using animation, I am able to give the participant visual aids to enhance the learning process of a topic [36]. As this lesson is designed to allow students with minimal background knowledge in astrophysics to participate, I used references to familiar objects and concepts to help the student solidify an understanding of the topic

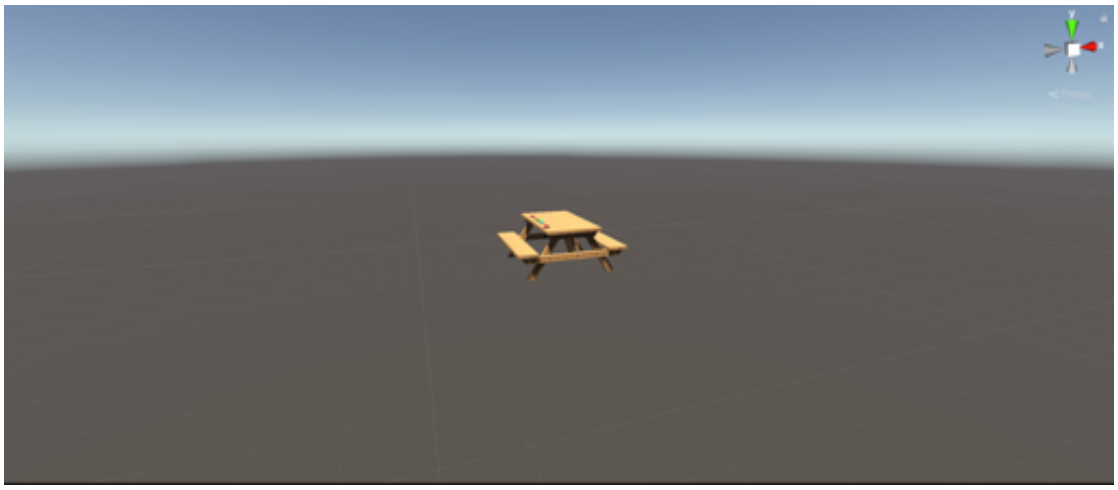

FIGURE 5.5: Default Environment.

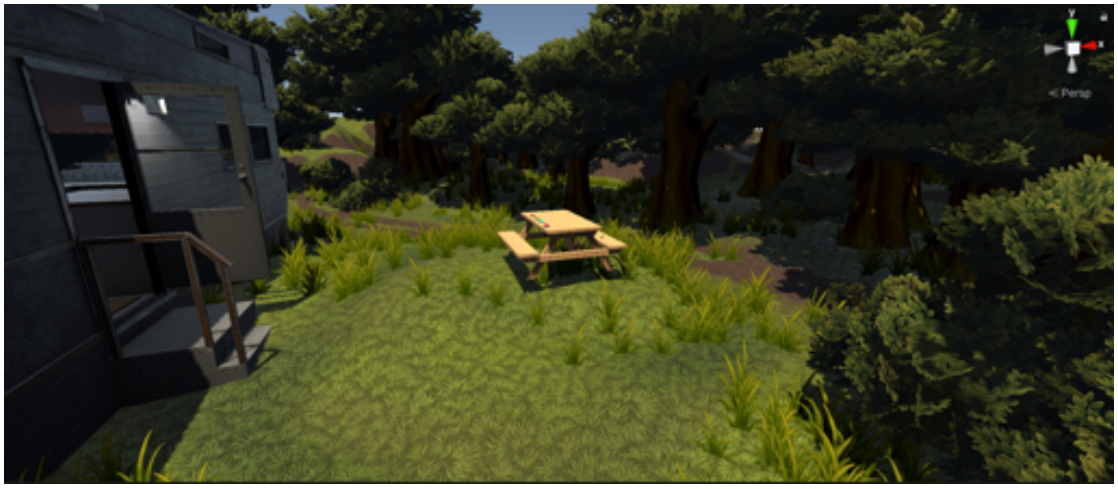

FIGURE 5.6: Daytime Environment.

[37]. For example, in order for the student to learn how the sun and earth are attracted to each other due to gravity, I compared this to a concept everyone is familiar with, humans being stuck to the Earth by that same gravity, or a ball falling to the ground when you pick it up and leave it go (see Figure 5.8).

To create the animation, a separate skill to traditional game development needed to be learned, that of animation, similar to how cut-scenes in a movie operate. I learned and utilised Unity's timeline feature, as described previously in this report, for this animation. The animation objects consists of visual aids with a mix of minimal text such as object tags and Newton's Equation. In total there are 94 tracks to the animation where each track corresponds to an object. To create a track I add the object to the timeline, and decide on the track type. A track can have the responsibility of spawning an object in or out of the animation or the responsibility of moving the object to make them dynamic. In order to not overwhelm the user with too much visual aid, I made

FIGURE 5.7: Adjusted Environment.

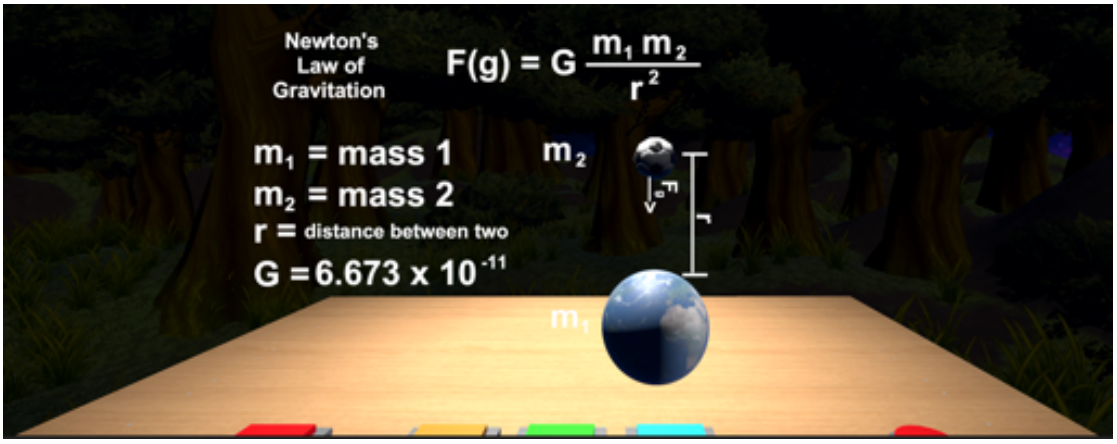

FIGURE 5.8: User learning about gravity by comparing it to known concepts.

use of unity's spawning tracks to de-spawn objects when they were no longer needed.

To create a spawning track, I add an object to the timeline and set it to active (see Figure 5.9). I then set the duration of the active state to make sure the object pops in and out at the correct time (in keeping with the narration). To make an object dynamic, I add a new track and press record. I then physically move the object within the scene and its movement(animation) is recorded.

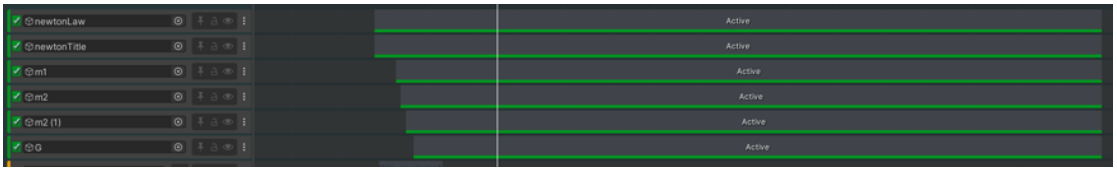

FIGURE 5.9: Adding spawn tracks to timeline.

The added benefit of using VR for education delivery is that I can animate objects in real-time to visual a concept in action, a feature traditional whiteboards lack.

5.3.1.4 Challenge

The main challenge with this component of the project was designing the animation / lesson in such a way that makes it as easy and as fluid as possible for the participant to understand the topic at hand. As I have no experience in teaching, I overcame this challenge by first, watching lecturers teach this concept on YouTube such as, Matt Anderson [38], in order to build a basis and create a structure, and second sourcing facts to ensure that my content is accurate [39], [40], [41].

5.3.1.5 Narration

5.3.1.6 User Interaction

For this lesson to take place I decided to implement buttons so that the participate could have full control over stopping / starting the experience. From my experience attending college remotely over the past year I saw the value in having access to recorded content. By being able to play back and pause video when I like, it allowed me to learn at my own pace which helped with more complex topics. It also allowed me to not move ahead until I fully understood the content being taught, as to not have gaps in my understanding. As a result, I decided to implement this control for the participants of this study (see fig.5.10).

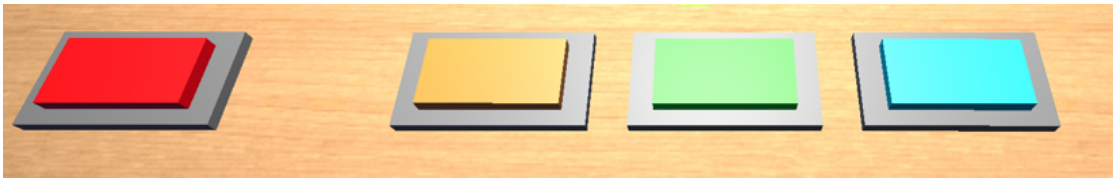

FIGURE 5.10: Buttons to control lesson.

To create these buttons I created two separate objects, the base and the push (coloured) object. The base object is a static object that cannot be moved by the user. The top part of the button was made move-able by adding a configurable joint component to the object. A configurable joint allows an object to be moved when interacted with, in a certain plane. By locking the X and Z planes I allowed the object to only move up and down (see fig.5.11).

I then added a script component so that when the button is pushed passed a certain threshold (distance) it activates the script to incite behaviour (see fig.A.1) & A.2).

The button works by having a reference to the configurable joint and timeline components. As the update method is called every frame, I implement a check (if statement) to

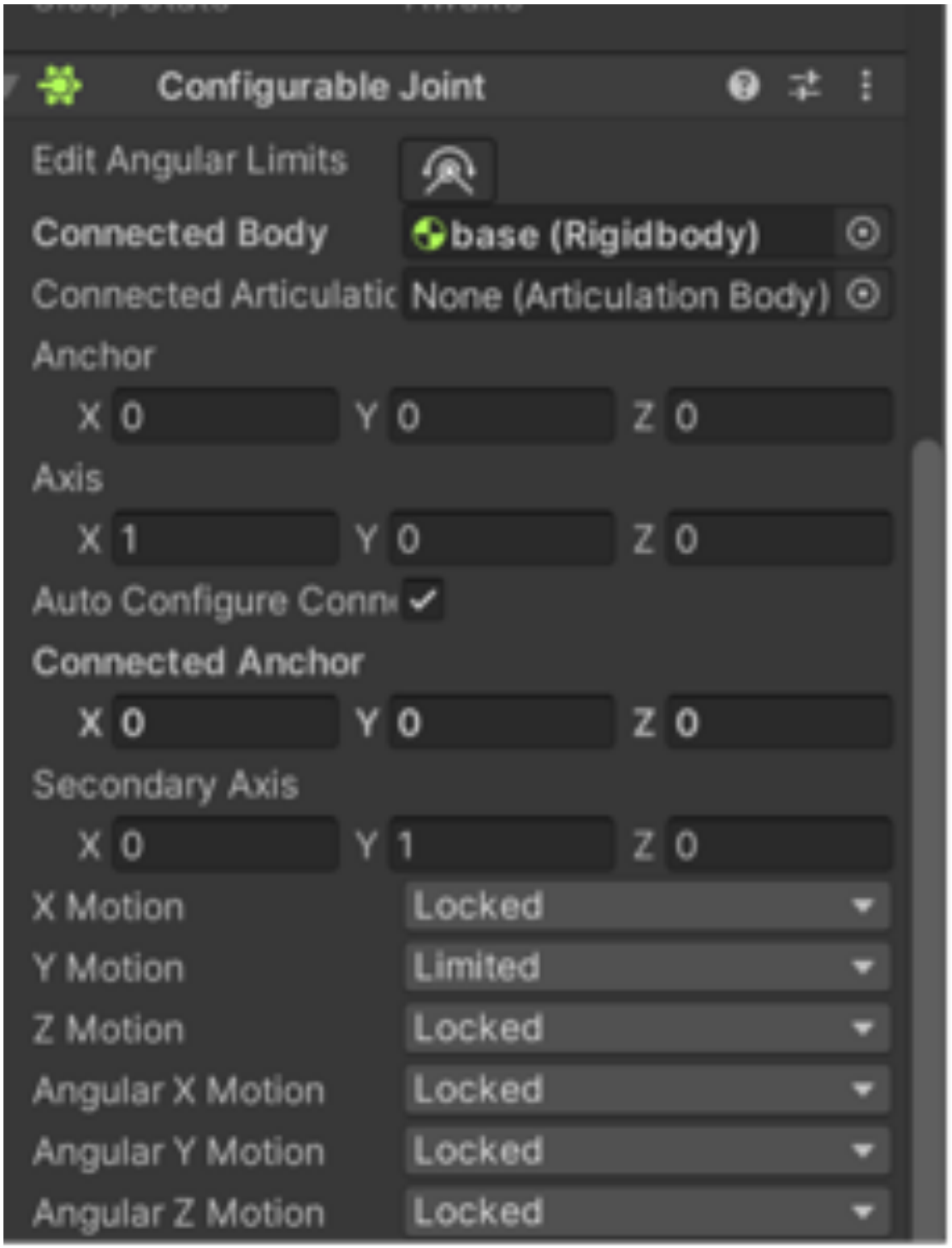

FIGURE 5.11: Joint component of Button Object.

see whether or not the push component of the button has been moved a certain distance in the Y direction, by calling a GetValue function. If it has moved a certain distance, I call another object called Pressed(). Pressed() is a function that defines what to do when the button has been pushed down. As this script is attached to all 4 buttons (play, Resume, Stop, Pause), I get a reference to the name of the parent object (string that

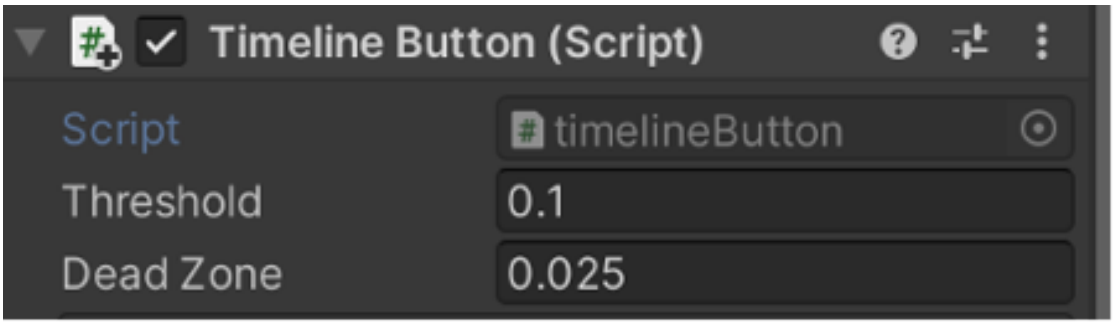

FIGURE 5.12: Joint component of Button Object.

identifies button) in order to differentiate between which button is in use. I then call the timeline object and its correct method to either Stop, Play, Pause or Resume the timeline animation.

There is a final button (see fig.A.3), that operates the same logic as the timeline buttons that allows the player to transport to scene two when they are finished with the lesson. This was accomplished by getting the user participant camera object and setting its X,Y,Z coordinates to the location of scene 2. This button also instantiates the objects of scene two as so to not have them rendering in during the lesson.

5.3.1.7 Challenge

The main challenge I ran into was when a button press happens, for the duration that the button is at that certain threshold in the Y plane (i.e pressed down), many updates are called due to many frames passing in the game. This is then picked up by Unity as the button being continuously pressed, so it would pick up as a user pushing the button many times as opposed to once. Initially, I did not know why this was happening, however I was able to debug and come up with a fix. I added a Boolean Value to the script, so that when the button is pressed, this value is set to true, and as long as this value is set to true, it will not register another press. This then led to the button not being able to be pressed again, so I added further code called Released(), which set the value back to false once the button leaves the threshold in the Y plane. So even though the update method gets called every frame, the additional conditionals in the if statement prevent the press function from being called more than once.

5.3.2 Scene 2

This scene consists of the user in space (see fig.5.13) and putting the knowledge learned into practice was not part of my initial design plan. This is due to not having decided

on what exact indicative content I would like to teach. The development steps of scene two were to implement:

1. atmosphere/environment
2. Objects and Object behaviour (scripts)

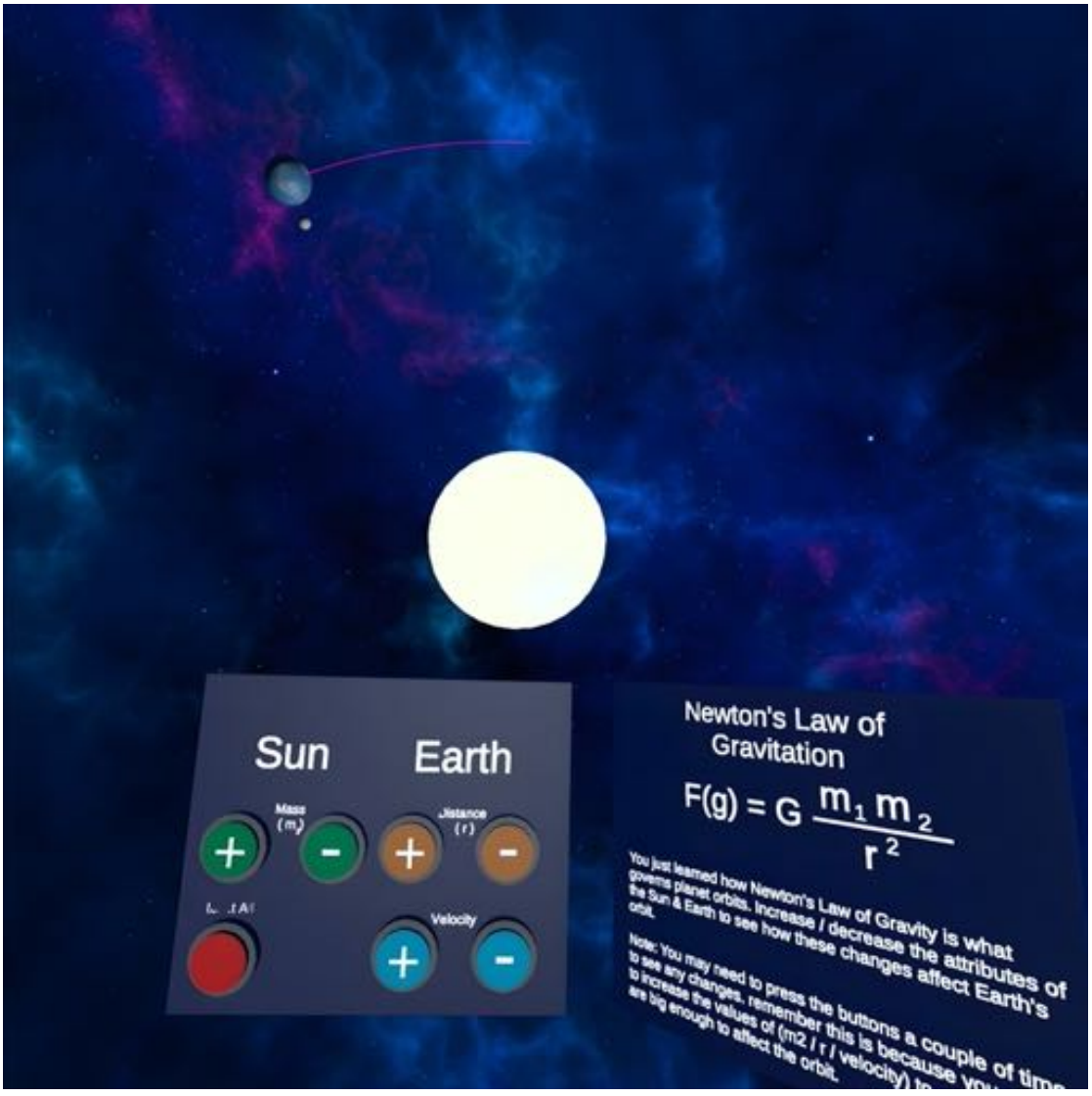

FIGURE 5.13: Scene 2.

5.3.2.1 Atmosphere

As the participant is now in space, an atmosphere was easily created by changing the skybox of the scene. The skybox is an image that wraps around the entire environment. By implementing an outer space skybox I again was able to create an atmosphere that feels realistic to the user as opposed to the blue / grey void.

5.3.2.2 Objects and Object behaviour (scripts)

This scene comprises of a foreground and a background. In the background, the Earth orbits around the sun and the moon orbits around the earth. The animation of these dynamic objects was far more complex then using timeline as these objects instead utilise the Unity Physics Engine. Again, I created three objects (sun, moon, earth) and attached a script to them to allow for this behaviour (see fig.A.4). I gave these objects relative values for their mass, where Earth mass = 1, and sun mass = 333,000 (as it is the size of 333,000 Earths). To implement orbit behaviour, I got a reference for the sun and earth objects in the script. I then created a function (Gravity) that utilizes Newton's Law of Gravitation. The function takes both objects as parameters, to use their attributes (mass and distance) to calculate the gravitational pull. This gravity function is continuously called in the update function so that the force of gravity can keep updating as it is dependent on the distance between both objects, which changes each frame.

I also created an orbitalSpeed function that gives Earth an initial velocity in the plane perpendicular to the sun. As Earth is initialized directly above the sun, I simply gave it velocity in the direction to the left (x plane).

The foreground consists of a panel with buttons that allow the user to manipulate the attributes of the Earth and Sun, which are a part of Newton's Law, to see how these changes affect Earth's orbit, in real-time. As the lesson is about Newton's Law of Gravity, I wanted the participant to see it in action. The button script layout is of similar logic to the previous timeline buttons, however, when the button is pressed, it instead changes the attributes of the planet to correspond with the button type (see fig.A.5 & A.6).

5.3.2.3 Challenge

As this section of the lesson utilizes the Unity Physics Engine, I needed to first fully understand the concept of Gravity and how it works, so that I could implement it correctly. This had me researching through different videos how this concept works as well as coming up with a solution on how to implement it.

5.3.3 Metrics

From my own experience as being a student in college, I know too well that student's can get distracted in class which as a result, hampers the learning process. this would

then result in the student possibly not fully understanding concepts and scoring lower on tests afterwards. To account for this with my study, I implemented three metrics that aim to capture the user's focus and level of engagement with the application. The idea was that by capturing this data, I could make more insightful conclusions. Output data of these metrics: (see fig.A.8)

5.3.3.1 Metric 1: Distraction

As stated above, student's can get distracted for many reasons in class. A usual indicator of a student not paying attention to a lecturer in class is when they are not focusing on the content/whiteboard situated in-front of them, instead they could be looking out the window or down at their phone. So, in order to replicate this observation in VR, in scene one I implemented a feature that detects when a user is not looking at the lesson. Even though I already made adjustments to the environment to lower the distraction rate of the student, by capturing this data it gives me actual measurable results of distraction.

I achieved this by utilizing a ray cast object in Unity with collision objects. A spherecast object is an object that beams off in a straight line and reports back if it interacts with another object. I then placed this spherecast object onto the user's camera to mimic exactly where they are currently looking. I then placed the collision objects around the user covering all areas that are deemed being distracted (see fig.5.14). I made these cubes invisible to the user. As there are many other objects in the scene, to avoid false positives where the spherecast picks up objects other than the cubes, I put them on a different layer. A layer in unity is a feature so allow for objects to only see and interact with other objects when on the same layer. So by dedicating a layer to this distraction metric, I avoided any false positives.

I then created a script(see fig.A.7) to handle for this collision detections. When the spherecast detections that the user is looking away, it increments a counter by 1 and starts a timer to capture how many times they look away and for how long. This data is then saved in a textfile on the headset with a function called saveData. Lastly, as the user has control over the playback of the lesson, I did not want the metric to count the user being distracted when the lesson is not in play. This was to mimic a student looking out the window when the lecturer has not begun the lesson, as they are not missing any content. So I added another part to the conditional to check whether or not the timeline was active.

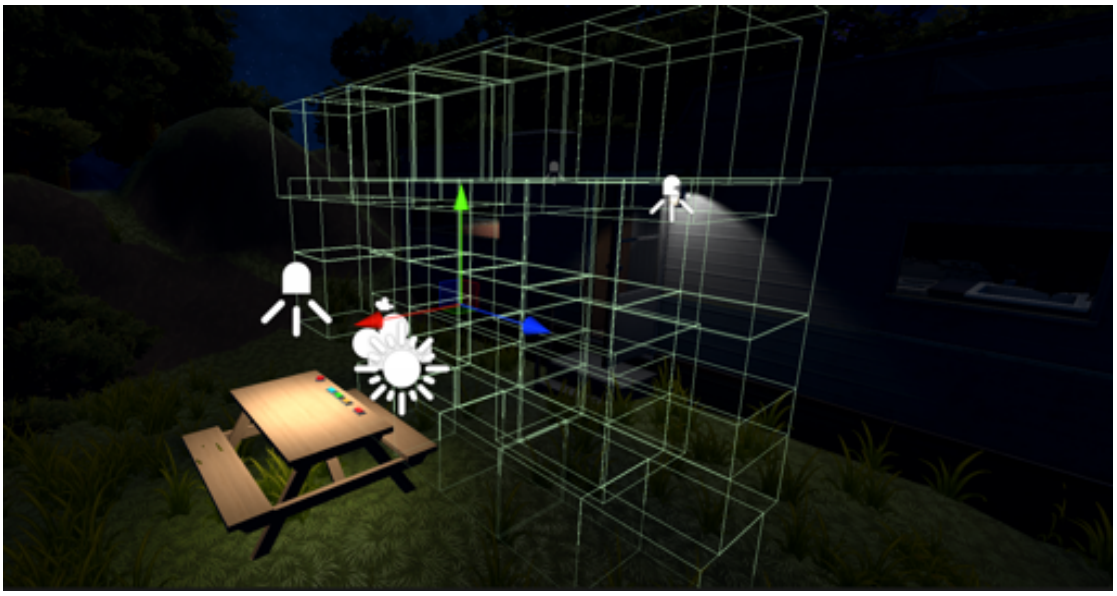

FIGURE 5.14: Collision cubes to capture user distraction.

5.3.3.2 Metric 2: User engagement

In scene 2, the user is to interact with the buttons to see how they affect Earth's orbit due to Newton's Universal Law of Gravitation, if the user does not interact with these objects, I deemed this similar to a student not doing any work during a practical lab session in college. So, to capture these metrics, I added counters to those buttons in space (see fig.A.5 & A.6) that capture all the times a user presses them. I then use the saveData() function again to save this data to a different textfile.

5.3.3.3 Metric 3: Time spent in-Game

Lastly, if a student did badly on the post test, I wanted to make sure that it was due to the VR device and not because they may have just skipped the content of the lesson and practical. So to capture this, I implemented counters that capture how long a student spends in each lesson. If a student was to score low on the post test, and this metric shows that they spent very little time on the lesson, it would allow me to make the conclusion that the user did not score well due to them not fully completing the lesson. I did this by starting a counter for scene 1 when it loads up, and when the teleport button is pressed, to go to scene 2, it saves this data to a third textfile on the headset.

5.3.4 Challenge (Metrics)

When developing an app for VR, you create it in the scene in Unity. However, as this scene is 2D (on a monitor screen) and the actual VR app will have a user in a 3D

scene, it is difficult to accurately capture certain aspects of how the VR app actually plays out, for example, knowing where exactly the user is looking. In order to overcome this, on Windows machines, developers can live connect their VR headsets to the PC and have it show updates to the game in real-time by putting on the headset without needing to trigger a rebuild. However, I develop on a mac, and this feature is not currently present. So as a result, I had to keep rebuilding the game every time I made the smallest adjustments if I wanted to see that it is acting as intended once in VR. This became a bottleneck when placing the distraction cubes around the user. I did not want to place the cubes in a location that would detect a distraction if the user looks slightly to the left / right in order to see the animations of the move, and due to the amount of times a had to move the cubes, I knew it would take a long time to adjust. In order to overcome this bottleneck, and make my development time more efficient, I created a debug menu (see fig.5.15) in the app so that when I build the VR app, I get live feedback in the headset to see when and where exactly the sphere detects a collision. I added the extra code required for this debug data, into the sphereCast script.

FIGURE 5.15: Debug menu turned on for development purposes.

5.3.5 Qualitative & Quantitative tests

In order for me to asses the level of engagements of students I had to conduct tests that measured these levels. I decided to create a both a qualitative and quantitative questionnaire for a post-test, as well as conduct a pre-test.

As a result of my research findings, I also decided to conduct a pre-test (see fig.A.9) for this project. By conducting a pretest it allowed me to gauge the users initial level of understanding of the subject. This would allow me to more fairly analysis the results to gauge how much students actually improved during the lesson. Initially, I was going to give the same paper to the students for the post and pre-test to see how their levels have improved. However, during the implementation stage when researching how to

design a pre-test paper I discovered that by conducting a test in this manner, it allowed the student to preemptively construct answers to the questions they did in the pretest, whilst completing the lesson [42]. So instead, I opted to create a test that gauged a students initial understanding of the topic without asking them directly the same questions, similar to how Jocelyn Parong (previous citation) conducted it in her article. The survey was to see if a users had had any experience with science topics and to also gauge their level of enthusiasm about the subject of astrophysics by asking them to self-rate on a score of 1-5. For example, if a student did not participate in any extra activities with relation to physics, completed any science modules in school / college, or showed any interest in science at all, it is fair to assume that they have zero-little understanding of physics concepts such as Newton's Universal Law of Gravitation.

For the post Quantitative test (see fig.A.11) it was designed to test the different aspects of Newton's Equation and how changing the values of the equation affected the orbit of Earth. This would allow me to gather factual information about how well a student received the lesson. As initially stated in this project, this report is to find out whether or not we can teach indicative content to students, so this test was deemed necessary.

I decided to include a post Qualitative test (see fig.A.10) to allow me to gauge the users level of excitement with VR technology. As this study is also about capturing a students level of engagement, by asking them to self-report how the feel after using VR, it would allow me to make conclusions with respect to the students engagement.

5.4 Limitations

Initially, I expected to conduct an experiment by gathering groups of students, maybe 30-40 from MTU, split them into a control and test group, and have them complete the lesson, one group with the VR device and the other group with traditional means of study. However, I ran into many hurdles that prevented this from taking place.

First: I have only one VR headset so this test would have to be conducted for each student sequentially, which would greatly increase the duration of the study and severely cut into my time for implementation of the actual application.

Second: During my semester two I contracted Covid so that pushed along any deadlines I had by two weeks due to my inability to do work. As a result this pushed all my deadlines for this project outwards, so when it came time to conduct the study, it was towards the end of the semester and students were preparing for exams.

Third: Time management. Initially I underestimated exactly how difficult it would be to implement the features of this experiment, which further push on the deadlines I needed to meet.

As result of the above three occurrences, I was only able to conduct the comparative with a size of 1 person in each group. I understand that by having a study group of such a small size does not allow for accurate or meaningful results to be drawn, so understand that the following results for the study are extremely anecdotal.

I had both participants complete the pretest survey and had the control group complete the lesson by reading the script of the narration for the content. The second participant utilized the VR headset for the lesson.

5.5 Metrics

As previously detailed in chapter 5, the metrics used for this experiment were a combination of surveys and in-game metrics to allow me to gauge how well a user learned the indicative content. The survey's provided me with a initial bar for each student's level of understanding of the topic and posttests that allowed me to gauge their improvement as well as their levels of engagement through a self-reporting qualitative test.

The 3 focus metrics allowed me to draw more finer conclusions by having more data to pull from and make assumptions as to why I got certain results.

5.6 Results

As there was only two participants in the study, I did not expect to be able to make much use of statistical analysis' such as the ones conducted in the papers from my research phase.

5.6.1 Summary of results

5.6.1.1 Control Group

The participant of this study had initially little to zero experience in science modules at an academic level, no participation in related activities such as attending science or research fairs and little interest in the field of astrophysics. So I made the assumption that this user had no understanding of how Newton's Law works.

For the quantitative post test the participant scored 1 out of the six answers correctly. An assumption could be made that the participant guessed the answer correctly as the test consisted of 6 questions where each question had 3 options.

Also for the qualitative test, the user scored unfavourably on the results, scoring a 1 out of 5 for enjoyment, 1 out of 5 for motivation and 1 out of 5 for interest in the subject. The results of this group may be handicapped by the fact that there was zero visual aid which may be found in textbooks when explaining such concepts or when taught at a university.

5.6.1.2 Test Group

The participant of this study had initially more experience in science modules at an academic level by completing science modules during school. No participation in related activities such as attending science or research fairs however. But there was a greater interest in the field of astrophysics as they answered yes to "I sometimes find myself on the internet looking up science related topics in my free time" . Also they scored a somewhat agree (4 out of 5) when asked about if they enjoyed watching space documentaries and a (3 out of 5) for "I would like to have a career in a science-related field". This leads me to make the pre-assumtion that they would score higher in the post test as they are likely to be more invested in the lesson as the chances of them knowing about Newton's Law of Gravitation are higher.

For the quantitative post test the participant scored 4 out of the six answers correctly. This is an increase from the control group by a wide margin. This allows me to make the conclusion that they did infact learn about Newton's Law. For metric one, it showed a value of zero times of being distracted during the lesson (as the file was not created due to there being no entry for distractions. Firstly, this could prove that the design of the VR lesson was successfully created in such a way that allowed for the user to give their undivided attention to the topic. However, it must be noted that they had a high initial interest in the topic so further testing would be needed in order to see how others fair. For metrics 2, button interactions, the student engaged with all buttons many times (35 presses in total(which shows that there was a high level of engagement in scene 2. Finally for metric 3, time spent in scenes, the user spent 11 minutes in scene 1 (the lesson is 8 minutes long) and a further (18 minutes in scene two). Concluding that the user more than likely completed the lesson in full.

For the qualitative study the user rated highly on each answer, saying that they are very interested in the subject, felt motivated to understand the material and would recommend VR to a user after competing this study. It should be noted that the user

had no prior experience with VR and the fact that they would know recommend it to a friend shows that it did have a positive impact on them.

Chapter 6

Discussion and Conclusions

6.1 Solution Review

Based on the anecdotal feedback form the evaluation stage it can be said that the VR solution to teach indicative content proved successful as well as it's ability to increase student engagement as they scored higher than the control group.

6.2 Project Review

I believe that if I had more effectively managed my time I would have got a more impressive result by having greater numbers for both groups of the study.

6.3 Future Work

For future work I could take two approaches, a quality of life features or expand on the content.

Due to the time constraints of this project, I built an MVP that lacks many features that would be expected of a commercial application. I would like to include a menu so that the user is not instantly thrown into the environment. this menu could also contain settings to allow the user to input custom attributes like their height so it would be reflected in the VR lesson. I would also like to add accessibility features such as a colour grade to allow for students with certain types of colour blindness. I would also like to utilize the lessons I learned from the module UE Theory and conduct a usability

test to see if my application has flaws in it's design that I may have missed during implementation.

For expanding the content, I could have the current lesson serve as one chapter and include more chapters about other aspects of astrophysics, such as Kepler's Laws. This would increase the selection of content and give the student more choice over what they would like to learn.

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Appendix A

Code Snippets

```
using System.Collections;
using System.Collections.Generic;
using UnityEngine;
using UnityEngine.Events;
using UnityEngine.Playables;
using System.IO;
using UnityEngine.UI;

public class timelineButton : MonoBehaviour
{

  [SerializeField] private float threshold = .1f;
  [SerializeField] private float deadZone = 0.025f;

  private bool isPressed;
  private Vector3 startPos;
  private ConfigurableJoint joint;

  private PlayableDirector timeline;
  public UnityEvent onPressed, onReleased;

  private float lookAwayCount;
  private float timeSpentWatchingLesson = 0;
  private bool isItPlaying;

  private GameObject sun;

    // Start is called before the first frame update
    void Start()
    {
      startPos = transform.localPosition;
      joint = GetComponent<ConfigurableJoint>();

      timeline = GameObject.Find("Timeline").GetComponent<PlayableDirector>();

      //sun  = GameObject.Find("sun");

    }


    // Update is called once per frame
    void Update()
    {
      if (!isPressed && GetValue() + threshold >= 1) {
        Pressed();
      }

      if (isPressed && GetValue() - threshold <= 0) {
        Released();
      }


      if (isItPlaying) {
        timeSpentWatchingLesson += Time.deltaTime;
        //Debug.Log("Playing");
        sun  = GameObject.Find("sun");
        if (sun.activeSelf) {
          saveData();
          //Debug.Log("Found sun active");
          isItPlaying = false;
          timeline.Stop();
        }
      }
      //Debug.Log("State " + isItPlaying);
    }


    private float GetValue()
    {
      var value = Vector3.Distance(startPos, transform.localPosition) / joint.linearLimit.limit;

      if (Mathf.Abs(value) < deadZone)
        value = 0;

      return Mathf.Clamp(value, -1f, 1f);
    }

    private void Pressed()
    {
      isPressed = true;
      onPressed.Invoke();
      timeline.Play();
```

FIGURE A.1: Button Script First half.

```
77
78      private void Pressed()
79      {
80        isPressed = true;
81        onPressed.Invoke();
82        timeline.Play();
83        //Debug.Log("Started");
84
85        var parentName = transform.parent.name;
86
87        if(string.Compare(parentName, "timelineButtonPlay") == 0) {
88          timeline.Play();
89          isItPlaying = true;
90          //Debug.Log("timelineButton");
91
92        }
93
94
95        else if(string.Compare(parentName, "timelineButtonResumeTemp") == 0) {
96          timeline.playableGraph.GetRootPlayable(0).SetSpeed(1);
97          isItPlaying = false;
98          //Debug.Log("timelineButtonRestart");
99
100       }
101
102       else if(string.Compare(parentName, "timelineButtonPauseTemp") == 0) {
103         timeline.playableGraph.GetRootPlayable(0).SetSpeed(0);
104         isItPlaying = false;
105         //Debug.Log("timelineButtonRestart");
106
107       }
108
109       else if(string.Compare(parentName, "timelineButtonStopTemp") == 0) {
110         timeline.Stop();
111         isItPlaying = false;
112         //Debug.Log("timelineButtonRestart");
113
114       }
115
116     }
117
118     private void Released()
119     {
120       isPressed = false;
121       onReleased.Invoke();
122       Debug.Log("Released");
123
124     }
125
```

FIGURE A.2: Button Script Second half.

```
using UnityEngine.Events;
//using System.IO;

public class buttonTeleportAction : MonoBehaviour
{

  [SerializeField] private float threshold = .1f;
  [SerializeField] private float deadZone = 0.025f;

  private bool isPressed;
  private Vector3 startPos;
  private ConfigurableJoint joint;

  private GameObject player, playerCam, FarCam, sun, earth, planetLight;

    public UnityEvent onPressed, onReleased;

    // Start is called before the first frame update
    void Start()
    {
      player = GameObject.Find("XRRig");
      playerCam = GameObject.Find("Main Camera");
      startPos = transform.localPosition;
      joint = GetComponent<ConfigurableJoint>();

      FarCam = GameObject.Find("MainCameraFarFinal");
      sun  = GameObject.Find("sun");
      earth  = GameObject.Find("Earth");
      planetLight = GameObject.Find("directionalLightPlanet");

      sun.SetActive(false);
      earth.SetActive(false);
      planetLight.SetActive(false);
      //saveData();
    }
    // Update is called once per frame
    void Update()
    {
      if (!isPressed && GetValue() + threshold >= 1) {
        Pressed();
      }

      if (isPressed && GetValue() - threshold <= 0) {
        Released();
      }
    }
    private float GetValue()
    {
      var value = Vector3.Distance(startPos, transform.localPosition) / joint.linearLimit.limit;

      if (Mathf.Abs(value) < deadZone)
        value = 0;

      return Mathf.Clamp(value, -1f, 1f);
    }

    private void Pressed()
    {
      isPressed = true;
      onPressed.Invoke();

      playerCam.GetComponent<sphereCast>().enabled = false;

      //Debug.Log("Pressed");
      player.transform.position = new Vector3(1.6f,250?f,504.79f);
      player.transform.eulerAngles = new Vector3(90f,0,0f);
      //playerCam.GetComponent<Camera>().nearClipPlane = 413.2f;
      //playerCam.GetComponent<Camera>().farClipPlane = 3?35f;
      FarCam.GetComponent<Camera>().enabled = true;

      sun.SetActive(true);
      earth.SetActive(true);
      planetLight.SetActive(true);


    }

    private void Released()
    {
      isPressed = false;
      onReleased.Invoke();
```

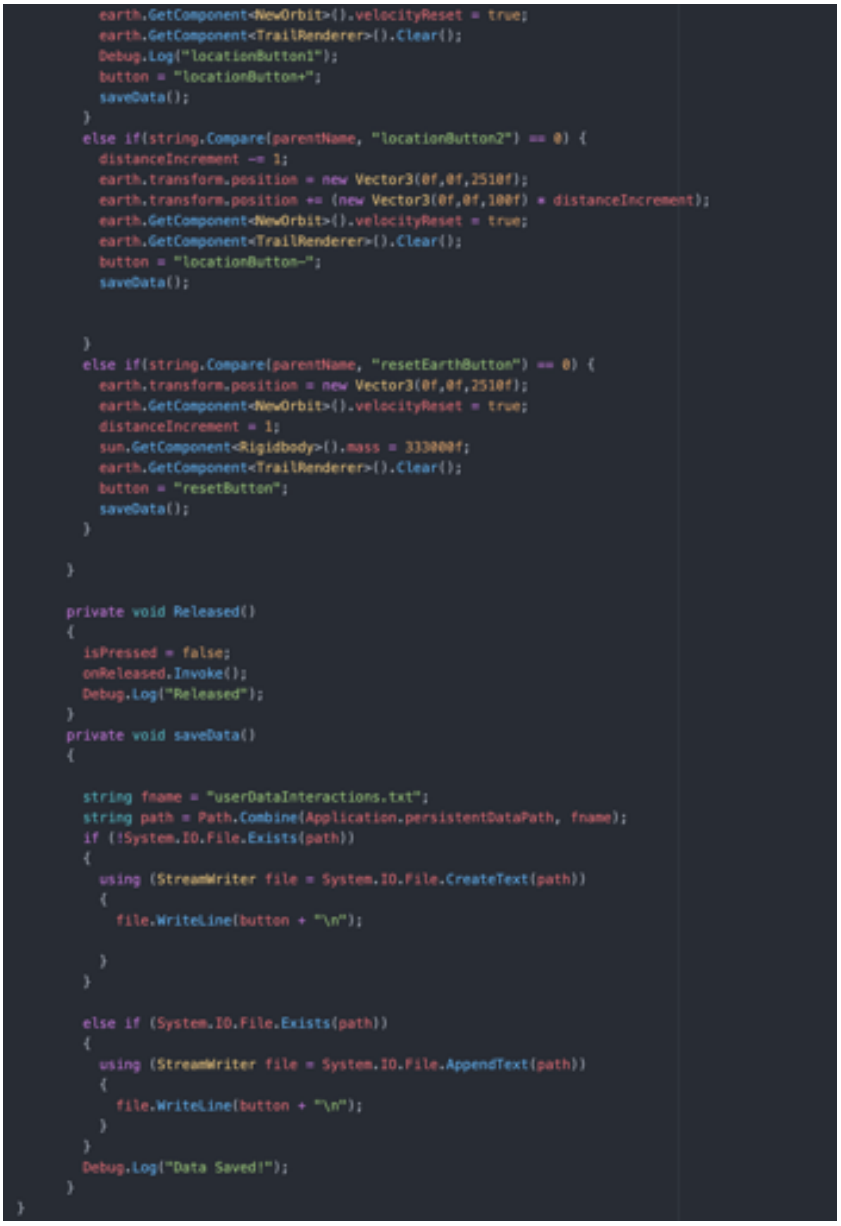
FIGURE A.3: Button Script to teleport user and instanciating scene 2 objects

```
using System.Collections;
using System.Collections.Generic;
using UnityEngine;

public class NewOrbit : MonoBehaviour
{
  private float gravity = 100f;
  private GameObject earth;
  private GameObject sun;
  public bool velocityReset = false;

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

      earth = GameObject.Find("Earth");
      sun = GameObject.Find("sun");
      //orbitalSpeed(sun, earth);
      orbitalSpeed(earth, sun, false);
    }

    // Update is called once per frame
    void Update()
    {
    }

    private void FixedUpdate()
    {
      Gravity(earth, sun);

      //Gravity(sun, earth);
      Debug.Log("velocity" + earth.GetComponent<Rigidbody>().velocity);

      if (velocityReset == true)
      {
        orbitalSpeed(earth, sun, true);
        velocityReset = false;
      }

    }
    void Gravity(GameObject planet1, GameObject planet2)
    {

      float massPlanet1 = planet1.GetComponent<Rigidbody>().mass;
      float massPlanet2 = planet2.GetComponent<Rigidbody>().mass;
      float radius = Vector3.Distance(planet1.transform.position, planet2.transform.position);
      Debug.Log("Radius" + radius);
      planet1.GetComponent<Rigidbody>().AddForce((planet2.transform.position - planet1.transform.position).normalized
      * (gravity * (massPlanet1 * massPlanet2) / (radius * radius)));
    }


    void orbitalSpeed(GameObject planet1, GameObject planet2, bool reset)
    {

      float massPlanet1 = planet1.GetComponent<Rigidbody>().mass;
      float massPlanet2 = planet2.GetComponent<Rigidbody>().mass;

      float aVal = 2500f - (massPlanet1 + 2);

      float radius = Vector3.Distance(planet1.transform.position, planet2.transform.position);
      planet1.transform.LookAt(planet2.transform);

      if (reset == false)
      {

      planet1.GetComponent<Rigidbody>().velocity += planet1.transform.right * 150;
      }
      else
      {
        planet1.GetComponent<Rigidbody>().velocity = planet1.transform.right * 150;

      }

    }

}
```

FIGURE A.4: Script that utilizes Newtons Law of Gravity to define an orbit trajectory of planets.

```
public class answerButton : MonoBehaviour
{
    [SerializeField] private float threshold = .1f;
    [SerializeField] private float deadZone = 0.025f;

    private bool isPressed;
    private Vector3 startPos;
    private ConfigurableJoint joint;
    private GameObject earth, sun;
    public UnityEvent onPressed, onReleased;
    private static float distanceIncrement = 1;
    private string button;

      void Start()
      {
        startPos = transform.localPosition;
        joint = GetComponent<ConfigurableJoint>();

      }
      void Update()
      {
        if (!isPressed && GetValue() + threshold >= 1) {
          Pressed();
        }

        if (isPressed && GetValue() - threshold <= 0) {
          Released();
        }
      }


      private float GetValue()
      {
        var value = Vector3.Distance(startPos, transform.localPosition) / joint.linearLimit.limit;
        if (Mathf.Abs(value) < deadZone)
          value = 0;
        return Mathf.Clamp(value, -1f, 1f);
      }

      private void Pressed()
      {
        isPressed = true;
        onPressed.Invoke();
        Debug.Log("Pressed");
        earth = GameObject.Find("Earth");
        sun = GameObject.Find("sun");
        var parentName = transform.parent.name;
        if(string.Compare(parentName, "massButton1") == 0) {
          Debug.Log("massButton1");
          sun.GetComponent<Rigidbody>().mass += 100000f;          //earth.GetComponent<TrailRendere
          button = "massButton+";
          saveData();

        }
        else if(string.Compare(parentName, "massButton2") == 0) {
          Debug.Log("massButton2");
          sun.GetComponent<Rigidbody>().mass -= 100000f;          //earth.GetComponent<TrailRendere
          button = "massButton-";
          saveData();
        }
        else if(string.Compare(parentName, "velocityButton1") == 0) {
          Debug.Log("velocityButton1");

          earth.GetComponent<Rigidbody>().velocity += 1.1f;
          button = "velocityButton+";
          saveData();
        }
        else if(string.Compare(parentName, "velocityButton2") == 0) {
          Debug.Log("velocityButton2");
          earth.GetComponent<Rigidbody>().velocity -= 0.5f;
          button = "velocityButton-";
          saveData();
        }
        else if(string.Compare(parentName, "locationButton1") == 0) {
          distanceIncrement += 1;
          earth.transform.position = new Vector3(0f,0f,2530f);
          earth.transform.position += (new Vector3(0f,0f,100f) * distanceIncrement);
```

FIGURE A.5: Script that changes attributes of the planets based on which button is pressed.



```
            earth.GetComponent<NewOrbit>().velocityReset = true;
            earth.GetComponent<TrailRenderer>().Clear();
            Debug.Log("locationButton1");
            button = "locationButton+";
            saveData();
          }
          else if(string.Compare(parentName, "locationButton2") == 0) {
            distanceIncrement -= 1;
            earth.transform.position = new Vector3(0f,0f,2510f);
            earth.transform.position += (new Vector3(0f,0f,100f) * distanceIncrement);
            earth.GetComponent<NewOrbit>().velocityReset = true;
            earth.GetComponent<TrailRenderer>().Clear();
            button = "locationButton-";
            saveData();


          }
          else if(string.Compare(parentName, "resetEarthButton") == 0) {
            earth.transform.position = new Vector3(0f,0f,2510f);
            earth.GetComponent<NewOrbit>().velocityReset = true;
            distanceIncrement = 1;
            sun.GetComponent<Rigidbody>().mass = 333000f;
            earth.GetComponent<TrailRenderer>().Clear();
            button = "resetButton";
            saveData();
          }

        }

        private void Released()
        {
          isPressed = false;
          onReleased.Invoke();
          Debug.Log("Released");
        }
        private void saveData()
        {

          string fname = "userDataInteractions.txt";
          string path = Path.Combine(Application.persistentDataPath, fname);
          if (!System.IO.File.Exists(path))
          {
            using (StreamWriter file = System.IO.File.CreateText(path))
            {
              file.WriteLine(button + "\n");

            }
          }

          else if (System.IO.File.Exists(path))
          {
            using (StreamWriter file = System.IO.File.AppendText(path))
            {
              file.WriteLine(button + "\n");
            }
          }
          Debug.Log("Data Saved!");
        }
}
```

FIGURE A.6: Script that changes attributes of the planets based on which button is pressed.

```
using System.Collections;
using System.Collections.Generic;
using UnityEngine;
using UnityEngine.UI;
using System.IO;
using UnityEngine.Playables;

public class sphereCast : MonoBehaviour
{
  [SerializeField]
  private LayerMask lm;
  [SerializeField]
  private float radius;
  [SerializeField]
  private float distance;
  private GameObject text, text2;
  private PlayableDirector timeline;
  private float lookAwayCount;
  private float lookAwayDuration = 0;

    void Start()
    {
      text = GameObject.Find("Text");
      text2 = GameObject.Find("Text2");

      timeline = GameObject.Find("Timeline").GetComponent<PlayableDirector>();

    }
    void Update()
    {
      RaycastHit rayCast;
      if (Physics.SphereCast(transform.position, radius, transform.forward, out rayCast, distance, lm
      && timeline.state == PlayState.Playing) {
        lookAwayDuration += Time.deltaTime;
        text.GetComponent<Text>().text = string.Format("{0:N5}", lookAwayDuration);
        Debug.Log("Hit");
      }
      else if (!Physics.SphereCast(transform.position, radius, transform.forward,
      out rayCast, distance, lm) && lookAwayDuration > 0)
      {
        lookAwayCount += 1;
        text2.GetComponent<Text>().text = string.Format("{0:N0}", lookAwayCount);
        //Debug.Log("FALSE");
        saveData();
        lookAwayDuration = 0;
      }
    }
    private void saveData()
    {
      string fname = "userDataDistraction.txt";
      string path = Path.Combine(Application.persistentDataPath, fname);
      if (!System.IO.File.Exists(path))
      {
        using (StreamWriter file = System.IO.File.CreateText(path))
        {
          file.WriteLine("Look Away Count: " + string.Format("{0:N0}", lookAwayCount));
          file.WriteLine("Look Away Duration: " + string.Format("{0:N5}", lookAwayDuration) + "\n");
        }
      }

      else if (System.IO.File.Exists(path))
      {
        using (StreamWriter file = System.IO.File.AppendText(path))
        {
          file.WriteLine("Look Away Count: " + string.Format("{0:N0}", lookAwayCount));
          file.WriteLine("Look Away Duration: " + string.Format("{0:N5}", lookAwayDuration) + "\n");
        }
      }
      Debug.Log("Data Saved!");

    }
}
```

FIGURE A.7: Script that detects and records user distraction.

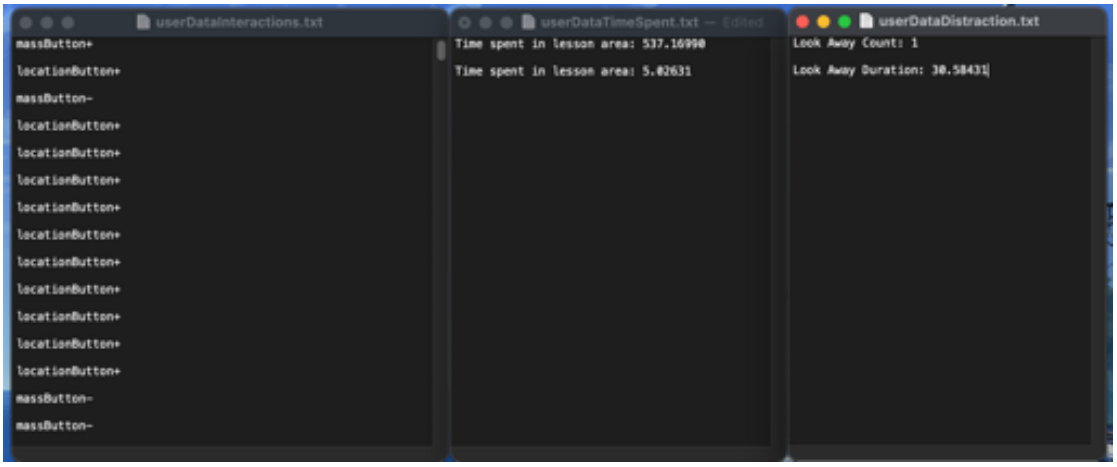


FIGURE A.8: User metrics.

Name:_____
Age: _____
Gender: _____

I have used VR devices before?

Yes
no

I have participated in science programs or research fairs?

Yes
No

I did a science degree in college related to either biology, physics, chemistry

Yes
no

I sometimes find myself on the internet looking up science related topics in my free time

Yes
No

I listen to podcasts about space, astronomy, astrophysics or physics

Yes
no

I have done a course (be it online course in person) in physics and astrophysics

Yes
No

I enjoy watching science documentaries about space or astrophysics

1 –Disagree 2 – Somewhat Disagree 3 – Neutral 4 – Somewhat Agree 5 –Agree

I would like to have a career in a science-related field

1 –Disagree 2 – Somewhat Disagree 3 – Neutral 4 – Somewhat Agree 5 –Agree

Science was my favourite subject in school?

1 –Disagree 2 – Somewhat Disagree 3 – Neutral 4 – Somewhat Agree 5 –Agree

FIGURE A.9: PreTest survey.

Name:_____
Age: _____
Gender: _____

I enjoyed this lesson

1 –Disagree 2 – Somewhat Disagree 3 – Neutral 4 – Somewhat Agree 5 –Agree

I felt motivated to understand the material

1 –Disagree 2 – Somewhat Disagree 3 – Neutral 4 – Somewhat Agree 5 –Agree

I am interested in learning more about this subject

1 –Disagree 2 – Somewhat Disagree 3 – Neutral 4 – Somewhat Agree 5 –Agree

I would now recommended VR devices to a friend after using one

1 –Disagree 2 – Somewhat Disagree 3 – Neutral 4 – Somewhat Agree 5 –Agree

Any additional comments to make?

_____
_____
_____
_____
_____
_____

FIGURE A.10: Post-Test Qualitative survey.

Name:_____
Age: _____
Gender: _____

Newton's Law of Gravitation

Using Newton's Law of gravitation, if the sun was to double in mass, what effect would it have on Earth's orbit?

1 – It would increase Earth's Orbit
2 – It would decrease Earth's Orbit
3 – None, mass does not affect orbit

Using Newton's Law of gravitation, what would happen to the sun's gravitational force on Earth if the distance between Earth and the sun were to decrease?

1 – It's gravitational force would be stronger
2 – It's gravitational force would be weaker
3 – It's gravitational force would be the same

The sun does not physically move towards Earth because?

1 – The moon pulls Earth away
2 – The sun has velocity
3 – The Earth's gravitational force acting on the sun is too weak

The Earth does not crash into the sun due to?

1 – It having enough velocity in the right direction to counter the sun's force of gravity
3 – The sun moving through space

If the Earth were to increase in velocity, what would the result be?

1 – It's orbit would increase
2 – It's orbit would decrease
3 – It would crash into the sun

If the Earth became the same size as the sun what would happen?

1 – The sun and the Earth would go further apart
2 – Nothing would happen to either planet
3 – The sun and the Earth would collide

FIGURE A.11: Post-Test Quantitative survey.

Appendix B

Wireframe Models