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Teaching VR Locomotion Techniques with VR: An Interactive approach within Higher Education

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Kalina Fedorczuk

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Dedication

Dedicated to my cat Toby, who has been with me since I was 11 and has assisted me through my life's hardest moments. I hope that we can continue to make many memories together.

I would also like to dedicate this paper to my other kitten Stitch, who has entered the household during the writing of this thesis and has been a silly bundle of joy. I hope that both of you enjoy sitting on the thesis for years to come when it's printed.

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Abstract

This paper explores the application of virtual reality (VR) in education, specifically focusing on the education of virtual reality Locomotion techniques within the VR environment. A comparative study is conducted to evaluate educational outcomes in this VR-based approach against traditional learning methods employed in Game Design University courses for teaching virtual reality. Additionally, the study addresses limited amount of teaching frameworks in virtual reality educational research by introducing an accessible teaching framework tailored for virtual reality instruction. The research further examines and compares educational outcomes between the implementation of the framework and scenarios where it is absent.

Twelve participants from the Game Design course engaged in an educational 10 minute virtual reality (VR) experience focused on teaching locomotion techniques. The experience included segments with the teaching framework and an alternate scenario without the framework. Participants reported higher enjoyment during segments with the framework and expressed increased feeling of educational outcomes. Additionally, participants noted superior educational outcomes in VR compared to traditional classroom approaches when learning VR locomotion techniques. More research is needed to better understand virtual reality as an educational tool.

Keywords: Virtual Reality, educational outcomes, teaching frameworks, Game Design, Locomotion techniques.

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1.1 Background

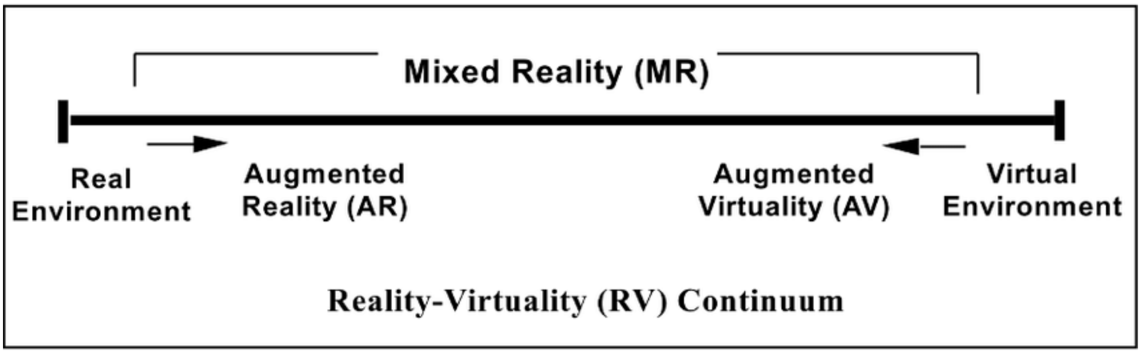

Figure 1 Reality-Virtuality Continuum (Milgram et al. 1955)

Virtual Reality (VR) in its simplest terms can be defined as a “three-dimensional, computer-generated, and interactive environment that can be explored by an individual”. (Brey & Søraker, 2009). The Reality-Virtuality continuum (Milgram et al. 1995) a continuous scale showing the complete virtual through to physical reality, this scale places virtual reality as a fully virtual environment with no elements of reality present. Virtual Reality typically provides interaction and immerses the user’s senses which sets it apart from other technologies as well as books and film (Schuemie et al. 2001).

The technology behind virtual reality dates as far back as the 1800s, evolving over time from the first Sensorama in 1956, to the Ultimate Display in 1965 (The Franklin Institute, 2016) and even the recent launch of the Oculus Rift in 2016 (Oculus, 2021). Knowing this virtual reality has become more widely popular as well as accessible to the average consumer with its estimated growth to be from 12 billion U.S. dollars to 22 billion U.S. dollars by 2025 (Alsop, 2022). While Meta has never disclosed the number of sales it has received on its Meta Quest 2 it has been estimated to have shipped around 10 million units by the CEO and president of Qualcomm, Cristiano Amon (2021) who works directly with Meta. With Sony providing figures of more than 4.2 million units of PlayStation VR sold as of 2019 (Shuman, 2019) the virtual reality industry is steadily growing and gaining more consumers with research in this area being more important than ever before. A system that used to cost thousands of dollars now costs only hundreds of euros (Slater, 2018). In addition, in 2021 the number of augmented reality and virtual reality devices shipped worldwide has reached 9.86 million units (Alsop, 2022). It is clear from evaluating the market that virtual reality is here to stay, and it is more crucial than ever to explore this field.

With the rising interest in virtual reality and more units sold than ever for the system, education in this field is more viable than ever. Virtual Reality has been explored in terms of education for a long time, primarily with the interest of enhancing learning and the ability to take users to new environments that are out of reach in the real world. Virtual Reality, while not being new, has become more and more accessible during the years with commercial virtual reality devices being available for more affordable prices than ever making it more accessible to use in education with headsets retailing at £299.00 for a Meta Quest 2 (Amazon, 2023). Additionally with the creation of the Google Cardboard, which only requires a mobile phone and the Google Cardboard itself it has become extremely easy to access educational immersive content in the immersive space.

Additionally virtual reality has begun being used outside of research in the education field with companies such as ClassVR (2022) translating standard curriculums to interactive and immersive forms in virtual reality itself and providing education to schools. Schools can purchase package deals by applying for a quote with ClassVR to use virtual reality in their classrooms. ClassVR offers packages from Pre-School education up until vocational courses for 18+ students. Virtual Reality is becoming more used than ever in education with many benefits such as being able to show students different situations such as road accidents and dangerous driving increasing the awareness of road safety to teaching communication skills and mathematical thinking for pre-schoolers in virtual reality (ClassVR, 2022).

A study conducted by Zhao et al. (2020) indicated that VR was associated with improved test scores when compared to other teaching methods used. These findings suggest that incorporating VR into the education can potentially lead to better academic performance amongst students. The immersive and interactive nature of the VR system may offer a unique learning experience that contributes to this improvement. Furthermore, Ogbuanya et al.'s (2018) research goes a step further by demonstrating that VR not only improves academic achievement but also increases a student's interest and engagement with the subject matter. This finding suggests that VR has the potential to foster a more positive learning environment which in turn can contribute to long-term educational success.

ClassVR (2022) is not the only company to attempt teaching through virtual reality with other companies such as the Google Expeditions Pioneer Program which provides schools with the technology and content to take their students to new places and environments through the technology itself (Mennuti, 2018). This is hugely beneficial by allowing students to travel to areas that otherwise they may be unable to travel to. Another company Unimersiv (2015) aims to create immersive educational experiences in Virtual Reality accessible to anyone teaching topics such as anatomy amongst many others. This company allows for anyone with a compatible headset to access the teaching resources. Despite this education in Virtual Reality is still highly inaccessible with little consideration given to the accessibility of teaching materials in Virtual Reality, little accessible teaching material is created for the use with commercial Virtual Reality headsets.

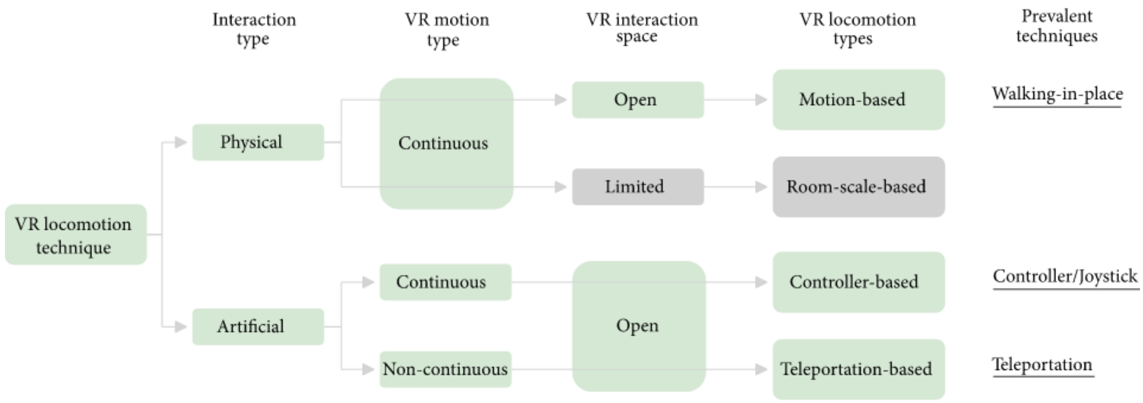

Figure 2 Locomotion Techniques in VR

Developing for Virtual Reality requires the understanding of techniques to develop good content for Virtual Reality. Hands-on experience is crucial in teaching virtual reality concepts (Burdea 2004) and with little teaching materials found in virtual reality itself it is clear that very limited materials are available to provide this hands-on experience. Locomotion is the technique which allows for movement from one place to another in an immersive environment with many ways to execute this all with their pros and cons (Wigmore 2022). It is essential that developers have a good understanding of the pros and cons of locomotion techniques when developing for virtual reality. Locomotion techniques come with challenges, for example they may be prone to causing motion sickness making it essential to understand well for developers. Research states that “the movement in VR should mimic the movement in physical space” in Virtual Reality (Ribeiro 2021). Virtual Reality locomotion is “an essential interaction component enabling navigation in VR environments” (Boletsis and Cedergren 2019). However, with such a visual concept where even the slightest difference can change how a person feels, it feels essential that developers learning this technique can experience locomotion in the immersive environment to further understand locomotion and its usage.

With the market for Virtual Reality rising yearly and Virtual Reality becoming more used than ever, it is important more than ever to teach developers how to develop content for Virtual Reality. It is difficult to find information on the exact way Virtual Reality is taught at universities, however, Teaching Virtual Reality (Bell, 1996) discusses a two-semester plan on teaching Virtual Reality, the approach of this plan is purely theory based and has no interactive elements using primarily textbooks to educate students. When researching education material on Virtual Reality, most content can be found as textbooks such as The VR Book: Human-Centered Design for Virtual Reality (Jerald, 2015) and video material available on websites such as YouTube (Google, 2005).

1.2 Research Problem

The problem quickly arises when one can consider how Virtual Reality is made of mainly visual techniques, such as locomotion. Research states that ‘hands-on’ experience is crucial in teaching concepts of Virtual Reality (Burdea 2004). However, very little hands-on experience can be seen in the current teaching materials available. One would think that using the system itself to teach future developers of Virtual Reality techniques would be the hands-on experience needed, however, limited information on this being done is present causing very little understanding in this field.

While there has been research done into other teaching in Virtual Reality such as in medical teaching (SAMADBEIK et al. 2018) and science-based teaching such as astronomy (Mintz et al. 2001) to teaching history in Virtual Reality (Villena Taranilla et al. 2022), there has surprisingly been very little research into using the system itself to teach future developers of Virtual Reality techniques such as locomotion or any other Virtual Reality techniques creating a gap in current research. Additionally, there is a lack of the use of frameworks when creating teaching material for virtual reality, potentially hindering learning outcomes (Fowler, 2015). Since Virtual Reality has proven to be extremely effective in teaching other subjects, it raises the following question, can Virtual Reality itself enhance the learning of future developers learning to develop for the system with the use of teaching frameworks? Virtual Reality for teaching is nothing new in research and teaching, with schools adapting Virtual Reality in schools to enhance teaching and learning due to the known benefits of Virtual Reality on education. It Is reasonable to assume that the benefits that Virtual Reality has on education may improve the learning of future developers on the system itself.

This research will focus on combining frameworks to understand and analyse if teaching Virtual Reality locomotion techniques and their impact on user experience in the system itself would be beneficial to the learning of University Students undertaking media and game related courses. This research will use the Virtual Reality locomotion techniques to understand this relationship due to the importance of this technique and the well-established understanding of locomotion techniques and their impacts on user experience. Lastly this research will involve University Students as participants who will take part in the immersive teaching tool and answer qualitative surveys to determine if teaching in Virtual Reality is effective and beneficial.

Understanding this relationship between Virtual Reality and teaching will benefit the research field by providing a deeper understanding on how Virtual Reality can be used in an educational aspect. This further understanding can also assist university courses and the industry itself in creating more effective courses that increase learning of Virtual Reality producing higher grades. The data collected in this research will contribute to the small amount of research done in this area, providing more information that can be used in future research furthering the field. Lastly by improving the way Virtual Reality is taught more immersive and effective experiences can be created both in the entertainment industry and for medical research.

1.3 Research Question and Objectives

Research Question:

1. What impact does teaching University Students Virtual Reality locomotion techniques in the system have compared to traditional teaching methods have on Game Design students?

2. What effects does teaching Virtual Reality locomotion techniques with a framework in the system have on students specializing in game design at the university level?

3. What effects does teaching University Students Virtual Reality locomotion techniques with a framework in the system have on Game Design students, in contrast to teaching the same techniques in the system without a framework?

Research Aims:

To create an accessible teaching tool supported by a newly created framework from a combination of frameworks for teaching in Virtual Reality in order to assess the potential benefits that teaching locomotion techniques and their impact on user experience may have on students.

Research Objectives:

1. Investigate the impact of locomotion techniques on user experience by conducting a literature review to inform the development of an effective teaching tool.

2. Identify and discuss existing frameworks for teaching in VR, utilizing the literature review to create an interdisciplinary, user-friendly teaching framework for locomotion techniques and their impact on user experience.

3. Assess the current accessibility of VR in education by analysing the teaching and research landscape through the literature review, aiming to determine the most accessible form of VR instruction.

4. Implement the developed teaching framework from the literature review to create a financially viable and easy-to-use teaching tool in VR, focusing on educating students about locomotion techniques and their impact on user experience.

5. Evaluate the perception of the teaching framework using a qualitative and quantitative survey with participants to understand and assess the effects of the developed teaching tool on students.

6. Compare participant views on the teaching framework, experiences without a framework, and traditional classroom methods using a qualitative and quantitative survey for a clear assessment of the effects of the experience on Game Design students.

Chapter 2 Literature Review

As established in the introduction of this thesis, the aim of this study is to explore if Virtual Reality can prove to be an effective tool at providing a better learning experience to students learning Virtual reality concepts. To understand this topic further it is crucial to explore the depths of locomotion, education in Virtual Reality and the frameworks available for teaching in the system itself.

This literature review will analyse and discuss Virtual Reality itself and its usage in education as well as explore the frameworks available that have been developed with teaching in Virtual Reality exclusively. The literature review will also address locomotion and the techniques used in Virtual Reality. Lastly this literature review will address the two objectives 'Review and identify the current tools and frameworks for teaching in Virtual Reality' and 'Explore and review the component of locomotion in Virtual Reality in order to implement the component effectively in the developed tool'.

2.1 Virtual Reality and Systems

This section will define Virtual Reality, discuss the uniqueness of Virtual Reality compared to other systems available as well as address the types of Virtual Reality available.

2.1.1 Defining Virtual Reality

Virtual Reality is a breakthrough technology as fantastic as the wonderful land Alice found down the rabbit hole with the only required being a pair of video goggles (Hoffman and Vu 1997). Allowing users to step into fully immersive worlds and environments to truly immerse themselves in the space.

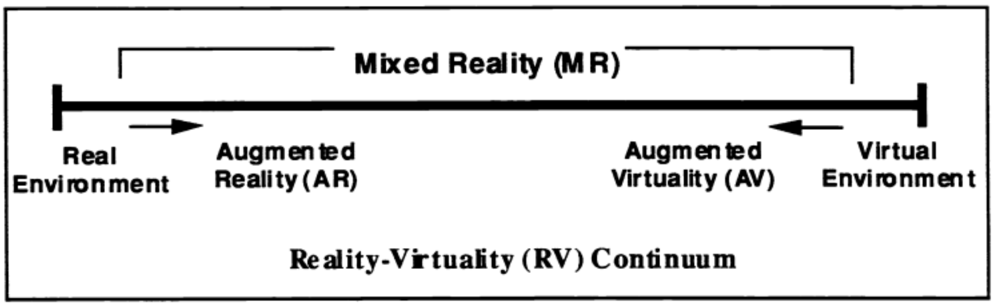

Figure 3 Reality-Virtuality (RV) Continuum

The Reality-Virtuality continuum (Figure 2) is a continuous scale showing the complete virtual and complete reality, this scale places Virtual Reality as a fully virtual environment with no elements of reality present. Virtual Reality typically provides interaction and immerses the user's senses which sets it apart from other technologies as well as books and film (Schuemie et al. 2001). Users can experience an immersive environment that closely represents reality, for example in some Virtual Reality systems users can move around in the real world and in return move around in the immersive environment, users can also look around and have this movement replicated in the environment as well as be able to manipulate the experience and objects around them leading to new possibilities in learning and gaming alike. The advantage of Virtual Reality lies in the ability to immerse users completely in a Virtual Reality with sounds, visuals and other stimuli. Virtual Reality has the ability to remove the interface ad directly place the user inside of the computer and human generated environment (Moore, 1995).

2.1.2 The Three levels of immersive VR (Lee and Wong, 2008)

VR can be classified into three different levels of immersive VR (Lee and Wong, 2008). Partially or semi-immersive VR can give the user the feeling of being slightly immersed by the environment, however, the user still feels aware of the real world around them. This differs hugely from the popular head-mounted systems used widely today. A semi-immersive VR system often includes the usage of desktop screens coupled with methods such as sensor-gloves and shutter glasses (Lee and Wong 2008). While this type of VR allows for a semi-immersive environment it is unable to fully take away the user from the physical world outside.

A fully immersive VR experience is defined as a system that completely isolates the user from the real world, this can often be seen as a head-mounted device with sensor gloves and sensors that translate movement into a virtual experience. (Lee and Wong 2008) This type of Virtual Reality can be often seen in commercial systems such as Playstation VR and Meta Quest 2 which completely transport the user to an interactive experience.

Lastly Augmented Reality is the last level of the immersive VRs, also known as Mixed Reality this experience uses the real-world with computer generated graphics to bring objects into real world scenes. (Lee and Wong 2008) One example of AR is the popular application Pokemon Go, which allows users to catch and interact with Pokemon with the use of their camera.

This research will use a system that provides a fully immersive VR experience to the user, isolating them completely from the real world. This allows the user to focus fully on the content shown to them in the virtual environment.

2.1.3 Meta Quest 2

The Meta Quest 2, previously known as Oculus Quest 2, has launched in October 13th 2020 (Meta, 2022) with an initial price of $299. This standalone headset features two motion controllers with the headset itself containing four tracking cameras on the front (Robertson, 2020). The Meta Quest 2 features a highly curated app store allowing for the user to access applications and games that have been verified and approved by Meta (Robertson, 2020). The device additionally allows for the connection to a computer to play games and use applications from other platforms, this can be done using what is called a Link cable, this allows users to access more applications and games that are not available on the curated store itself. The advantages of the Meta Quest 2 lie in its standalone nature, providing the user with the ability to use the headset on the go without any additional equipment required additionally making the headset easier to store at home. Additionally, the headset allows for the use of applications from more sources than the curated store, allowing for more freedom and usability. Despite this the headset comes with drawbacks, many users have reported the headset being heavy and containing a short battery life of 2-3 hours (Sutrich, 2023).

2.1.4 Google Cardboard

Google Cardboard (2014) is a virtual reality platform that does not have any electronic components but relies on the use of a smartphone to provide the user with an immersive 360 experience. The Google Cardboard is a headset created fully out of cardboard that must be assembled by the user before use, this headset comes with an affordable price tag of $15 per unit (Schroeder, 2016) making it extremely affordable and accessible to use for the average consumer. The headset contains no sensors, and all motion control is taken from the smartphone used in the headset, the headset is also unable to communicate with the phone to activate 360 apps with this having to be done by the user when using applications such as the Google Cardboard or the YouTube application. The use of Google Cardboard can be well observed with YouTube's 360 videos feature, as the user puts the headset on, they become able to move their head and look around the space in the video as if they were there themselves. The advantages of the Google Cardboard are clear, with its affordable price and ease of use it is the most accessible system to the average consumer, allowing consumers to immerse themselves in content on their smartphones that they would otherwise be unable to experience. Despite this, the Google Cardboard does suffer with drawbacks, with a lack of motion sensors as well as controllers there is very little interactivity with the content itself, the user is only able to look around the space but is unable to interact with it preventing from creating more immersive and interactive experiences for the system. The headset also requires to be always held, increasing tiredness experienced by the user and requiring experiences to be short.

2.1.5 Omni-Directional Treadmill

The Omni-Directional Treadmill (Virtuix, 2014) is a mechanical device that replicates a real treadmill, allowing the user to perform 360 locomotion, this system allows for natural movement in Virtual Reality without the fear of collision creating a much safer experience. The omni-directional treadmill requires the user to place themselves into a harness and use a headset to immerse themselves in the space, using cameras and trackers the Omni-directional treadmill will recreate the user's walking in the real space into the immersive environment itself. The device features a safety ring with an adjustable height, tracking capsules that attach to the user's shows as well as the Omni purpose built shoes themselves. The unique foot tracking capability of the Omni-directional Treadmill allows for extremely responsive movement and speed, when a user changes direction or speed the tracking will translate this motion into the experience itself, the system additionally allows for jogging, squatting and leaping (XRTODAY, 2022).

Despite the Omni-Directional Treadmills offering a big amount of immersion with the most natural way of walking the system is very rarely used for video games and applications. With the omni-directional treadmills ranging on retail from $1,995 to $2,295 the product is not accessible to the public. Additionally, a great amount of space is required to setup and run the Omni-Directional treadmill which many consumers will not have available in their homes.

2.1.6 Playstation VR

The PlayStation VR (Sony, 2016) is fully immersive headset created by Sony. The Playstation VR can be compared in some aspects to the Meta Quest 2, both devices feature a headset with controllers which register and track the user's movement in the immersive space. The Playstation VR, however, requires for the use of a PlayStation 4 or 5 console with a PlayStation Camera which powers the headset itself and allows the user to play games unlike the Meta Quest 2 which is a standalone headset. The system features a 5.7 inch OLED display with a resolution of 1080p, with nine positional LEDs on its surface the system uses the PlayStation Camera to track 360 degree head movement. The advantages of the PlayStation VR include it's commercial availability, the PlayStation VR does not require a lot of space with the user able to use it in their home, additionally the system also features a fully curated store keeping the user safe from viruses. However, the system does not allow for the use of applications outside of the PSN store disabling the user from downloading content from other store fronts that may not be available on the PSN store.

2.1.7 Discussion

This chapter has discussed and identified what Virtual Reality is using the Reality-Virtuality Continuum (RV), and has identified the three levels of immersion that can be provided by Virtual Reality. To accurately identify this thesis, it is crucial to discuss what type of Virtual Reality will be used including the three levels of immersion as well as the justification behind these decisions.

Virtual Reality will be used in its most immersive form, this project will use a fully immersive Virtual Reality experience completely isolating the user from the real world in a head-mounted display, specifically the Meta Quest 2. The Meta Quest 2 is an accessible commercial form of a Virtual Reality headset, and it can be assumed that an educational institute is more likely to have the Meta Quest 2 over the omni-directional treadmill or PlayStation VR due to the cost required. The Meta Quest 2, requiring only a mobile device, allows for portability with no extra required equipment such as a console or controllers to use providing increased accessibility. Additionally, the Meta Quest's ability for the user to both stand and sit while using the system allows for better accessibility compared to a device such the Omni-directional treadmill which cannot be used for individuals with certain disabilities. Considering the advantages discussed, the Meta Quest 2 is the option with the most advantages for the use case discussed in this Thesis allowing for most immersion and accessibility allowing for the creation of an accessible teaching tool using Mozilla Hubs.

2.2 Education in Virtual Reality

The following section will address education in Virtual Reality as well as its effectiveness and accessibility.

2.2.1 Teaching in Virtual Reality

Virtual Reality has been gaining recognition due to its enormous educational potential (Hoffman and Vu 1997). In an article titled 'Virtual reality: teaching tool of the twenty-first century?' Hoffman and Vu (1997) make an important distinction between the usage of Virtual Reality and standard computers in education. Stating that one of the appeals of Virtual Reality is the ability to manipulate your environment and be fully immersed in the experience, freeing students to focus their whole attention on the experience rather than on the computer interface that would be present in a standard learning experience. This distinction means that students can keep their full concentration on the immersive teaching experience without having to learn and understand the computer interface otherwise present, removing this barrier in teaching allows for more focused teaching of subjects. Hoffman and Vu (1997) also state that due to the highly visual nature of a VR system, it ‘can be used to create knowledge-building experiences that facilitate the comprehension of complex 3-D subjects (e.g. anatomy).’ (Hoffman and Vu (1997). While this article highlights the valuable strengths of teaching in Virtual Reality, especially in terms of teaching complex 3-D subjects in Virtual Reality, on the other hand it can be considered outdated being written in 1997 and may not apply to the current climate. Additionally, the article mainly discusses the capability of teaching in the system with very little studies shown to back these hypotheses. As this article has been written quite early into the field of teaching through Virtual Reality, it can be easily understood how little data is available to discuss.

A study performed shortly after, uses Virtual Reality to create a teaching environment for teaching of astronomy, developing a learning experience for the education of the solar system enabling users to move around the experience, zoom in or out changing their viewpoint and perspective enabling more powerful learning that can be used when teaching students astronomy (Mintz et al. 2001). This study portrays the strengths of using Virtual Reality in education, the ability to present 3D concepts, such as the solar system, in a digestible and interactive form. Students are unable to visit places such as the solar system, using Virtual Reality these experiences can be made possible with the ability to move throughout the solar system.

The US Defense Force has used VR to train people in combat techniques, navigation of vehicles from aircrafts to aircraft carriers (Psotka, 1994). Additionally repairs for the Hubble Space Telescope were first simulated in a Virtual Reality environment before the actual repairs were done, doing so prepared the workers for the dangerous conditions they would experience in the mission itself (Moore, 1995). Showing that Virtual Reality has increased potential in preparing workers for dangerous and important missions without putting people at risk while doing so. Research has shown that these applications can teach people to learn to perform tasks in the Virtual World that are accurately transferrable to the real world (Moore, 1995). The research highlights that the value of Virtual Reality for education lies in the ability to provide immersion to the user in realistic, novel or even abstract environments. It allows the user to manipulate their space, making visual and kinaesthetic relationships to help understand real world concepts. It may also bring information to the user which may not be accessible in a traditional learning environment (Moore, 1995). It is, however, important to consider the dates of the studies discussed and how technology may have evolved since the dates that these studies have taken place, outcomes may potentially be different with the rise and change in Virtual Reality systems over the years.

2.2.2 Accessibility of Virtual Reality in Education

Using Virtual Reality in education can be difficult, with the costs of such systems costing hundreds per device, there can be little opportunity to incorporate Virtual Reality into education. Schools often may not have enough funds to incorporate the system and software into their classrooms. Concerns may also arise with the lack of curriculums that allow for Virtual Reality learning. Companies such as ClassVR (2022) have attempted to incorporate traditional curriculums into Virtual Reality offering packages to schools that can be purchased for the classroom. While this takes away the concern of setting such systems up as well as purchasing the correct software, it does not address the heavy costs of incorporating these systems into the classrooms.

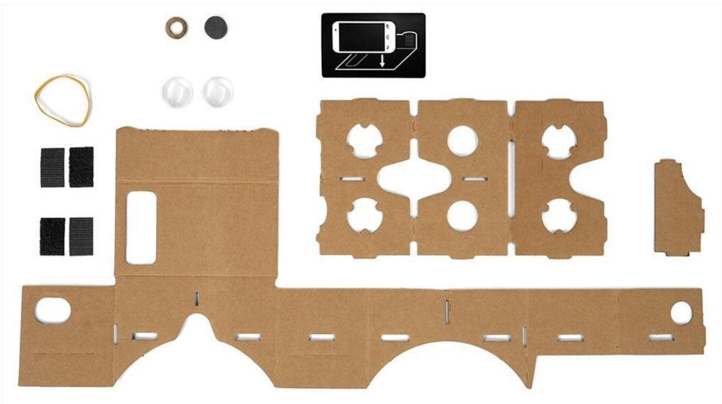

Figure 4 Google Cardboard laid out before assembling

One way to make Virtual Reality more accessible is using peripherals such as Google Cardboard (Figure 3). The Google Cardboard, completely made of cardboard, is easy and cheap to produce. The only component required is a standard smart phone which can be inserted into the headset to watch 360 contents. However, the Google Cardboard does not allow for an interactive experience that can be experienced with other devices such as the Meta Quest 2 making it a less immersive and interactive experience. This poses issues and is understandable why Virtual Reality has not seen a big uptake in education, it is crucial to consider the accessibility of this technology when developing teaching content for students.

2.2.3 Effectiveness of teaching in Virtual Reality

Teaching in Virtual Reality has become more and more common with research studying the effectiveness and potential benefits of teaching in Virtual Reality. A study titled 'The effectiveness of virtual reality-based technology on anatomy teaching: a meta-analysis of randomized controlled studies' (Zhao et al. 2020) examined the usage of Virtual Reality for teaching students' anatomy. Using randomized controlled research containing 816 students, the results from this study indicated that the use of VR for learning improved test scores moderately compared with other teaching tools. While the study has stated that the research used did not all use the same methods, this was accounted for in testing.

Another study titled ‘Effectiveness of Virtual Reality for Teaching Pedestrian Safety’ (McComas et al. 2002) studied if a virtual reality experience can improve children’s awareness on pedestrian safety and in turn increase safety. Ninety-five children participated in this study from urban and suburban schools, after three sessions there was a significant change in performance concerning the children from the suburban school but there was a lack of improvement in children from the urban school which may be explained by the number of students whose first language was not English. It is important to note that the study does not use Virtual Reality head mounted displays. Additionally, the study suggests the usage of more VR programs more aligned with reality in the future, however, results show that VR can be a promising tool in education.

A similar study titled ‘Effectiveness of virtual reality for teaching street-crossing skills to children and adolescents with autism’ (Naomi Josman et al. 2008) examines the usage of Virtual Reality in children with autistic spectrum disorder (ASD) to improve safe street crossing. Half of the experimental group, containing six children with ASD, made significant improvement in pedestrian behaviour in a real-street setting. Despite the small sample size used in this study, considering the previous study undertaken by McComas et al. (2002) has shown similar results it can be argued that Virtual Reality has strong potential to improve the learning of students. It is crucial to keep in mind that technology has vastly changed since the studies discussed, therefore the studies discussed may be outdated.

Meanwhile it is clear that Virtual Reality has a profound effect on learning, it is unclear the effects that Virtual Reality would have on teaching future developers Virtual Reality techniques such as locomotion.

2.2.4 Discussion

This section has explored and identified the current state of education in Virtual Reality, addressing both the methods in which Virtual Reality has been used for teaching and its effectiveness based on research. The current research suggests that Virtual Reality increases learning outcomes of participants and may be an effective tool in supporting learning. The ability to provide students with an immersive experience that can be manipulated and explored in a way that cannot be achieved with a traditional display gives opportunity to develop and create new ways of learning complex 3D concepts and even skills that can be otherwise considered dangerous to perform. The studies discussed demonstrate the current teaching climate in Virtual Reality, with many studies having tested Virtual Reality as a tool for learning in subjects such as astrology, anatomy, and skills such as street safety, however, the limitation of the current research includes the lack of concrete teaching frameworks used to inform the design of the educational experiences potentially causing lesser teaching outcomes than possible otherwise with the use of teaching frameworks. Additionally, very little research has been performed into teaching Virtual Reality concepts in the system itself, and none have been found that examine the teaching of locomotion in Virtual Reality which this thesis will be addressing. Finally little accessibility is discussed and considered in the papers reviewed, causing very little consideration to be given to how Virtual Reality teaching can be implemented in a classroom.

2.3 Virtual Reality development tools

This section will discuss in detail the tools considered as part of the thesis, each tool will be described in detail including it's features, advantages and disadvantages. The section will be followed by a discussion that analyses, compares, and discusses the chosen development tool that best supports the study.

2.3.1 Spatial.io

Spatial.io (2016) is a free to use platform for users to easily develop content for Virtual Reality. Spatial.io focuses on making the process of developing content for Virtual Reality easier and accessible to more people that may otherwise be unable to develop for the system. Using unity, Spatial.io features a website where users can login, create their unique avatars and organise virtual spaces to use how they see fit. Users can create spaces using pre-made environments by the software, such as an art gallery or a conference room and shape the environment to their specific needs, all accessible in your browser with no requirements to download any software. Users can additionally import 3D assets from websites such as sketchfab, their own PC, documents, images and video files which then can be used to build the virtual environment required. Spatial.io additionally allows for voice calls, screen sharing and video calling in these virtual spaces, creating a stronger learning environment for users. Another advantage of spatial.io is it's capability to be used both in the browser and in Virtual Reality headsets such as the Meta Quest as well as having support for mobile devices through the App store and Google Play Store, making the software extremely accessible to use with no cost. Members can also expand their experience with paid content for features such as live translations, ability to remove and mute participants, allowing up to 500 participants in your spaces and gating access to your spaces (Spatial.io, 2023). The advantages of using Spatial.io include the easy accessibility across various devices, no cost attached to basic features allowing users to experience spaces easily, ability to have voice and video calls in spaces allowing for a more personalised learning experience as well as the ease of development in Spatial.io. The software doesn't come without its disadvantages, developing in Spatial.io can be considered quite simple with little ability to control the environment around the user, there is no scripting, no camera movements making users unable to create more advanced experiences.

2.3.2 Mozilla Hubs

Mozilla Hubs is an open-source free to use tool developed by Mozilla in 2018, the software has first launched as an experimental project to assist users from different industries to try out VR collaboration (XRTODAY, 2021), however, with its increased popularity the software has branched out to include features such as galleries, classrooms and other spaces. Additionally, the software allows for the usage of other tools such as Spoke, a web-based development tool created to build spaces in Mozilla Hubs, allowing for more detailed environment creation as well. Other supported tools include Blender, Vartiste and gIFT Sample Viewer (Cool, 2022). The described tools turn Mozilla Hubs from a standard Virtual Reality software to a powerful space that can be customised and manipulated into advanced learning spaces. The tool additionally offers the ability to access spaces through a wide range of devices ranging from the Meta Quest 2, HTC Vive, Windows Mixed Reality as well as the Google Cardboard (Mozilla, 2023) allowing for improved accessibility compared to other softwares such as Spatial. Lastly Mozilla Hubs supports the import of models, audio, PDFs, documents, videos and other media allowing learners to experience a varied amount of content in the virtual space. The drawbacks of Mozilla Hubs include the lack of coding preventing more interactive immersive experiences, lower graphical fidelity as well as the lack of more personalised immersive environments.

2.3.3 Unreal Engine

Unreal Engine is a real-time 3D creation tool for immersive experiences first showcased in the 1998 first-person shooter game “Unreal” (Epic, 1998). Unreal Engine supports a wide range of tools to allow developers the freedom to create highly customisable and advanced immersive experiences, with its unique blueprint feature users are not required to have knowledge on programming setting it apart from many other engines. Unreal Engine’s benefits lay in it’s huge range of tools allowing for more interactive immersive experiences with the ability to code actions into the experience, strong environment manipulation allowing for varied and detailed environments as well as it’s strong capabilities laying in fidelity. Additionally Unreal Engine can be used in games, film & media, architecture, automotive & transportation, broadcasts & live events and simulations (Epic, 2023) allowing for a varied and precise use of the tool. Despite this Unreal Engine has some setbacks, as Unreal Engine is not a pre-built tool such as Spatial.io or Mozilla Hubs immersive experiences must be developed fully from scratch. Additionally the tool is not Virtual Reality ready as the other tools discussed, Spatial.io and Mozilla hubs, requiring more in depth development to achieve a Virtual Reality ready environment that does not have to be considered with the other mentioned platforms. Lastly Virtual Reality ready experiences created in Unreal Engine cannot be used in more accessible Virtual Reality devices, such as mobile-powered Google Cardboard, but rather if the experiences are to be accessed through the Google Cardboard itself they must be shown as a 360 Video, taking away an aspect of interactivity that is available in Mozilla Hubs.

2.3.4 Discussion

The following section has discussed and compared available softwares and tools for developing immersive environments for Virtual Reality. Advantages and disadvantages of both Mozilla Hubs, spatial.io and Unreal Engine have been discussed with considerations in mind such as accessibility, interactivity and features available in each software. From comparison it can be established that the most appropriate software is Mozilla hubs, with support for additional tools that can be utilised to create more immersive dynamic environments and wide accessibility allowing students to participate in learning using mobile powered Virtual Reality systems such as the Google Cardboard. Despite spatial.io featuring similar aspects to Mozilla Hubs with the ability to import 3D models, videos, images and documents, the software lacks in its accessibility with only allowing the usage of a Meta Quest 2 which may not be easily accessible to students. In conclusion Mozilla Hubs best satisfies the aims of this project. Additionally a tool such as Unreal Engine, while extremely powerful, requires increased work from scratch to develop an immersive environment especially for use in Virtual Reality, keeping in mind the scope of the project with the limited timeframe it would not be beneficial to use Unreal Engine compared to a software such as Mozilla Hubs which allows easier development for Virtual Reality. Lastly using a tool such as Unreal Engine may not allow for correct and full implementation of the teaching frameworks required with the limited time frame.

2.4 Locomotion

2.4.1 Defining Locomotion

Locomotion is an essential component in Virtual Reality enabling navigation in VR environments. This essential part of Virtual Reality has been transformed and developed in many ways over the years, with better design decisions incorporated to create a more comfortable moving experience which is more user-friendly (Boletsis and Cedergren 2019).

Locomotion is the sole technique allowing users to move around the immersive experience, users can move using locomotion in a variety of ways. Some devices such as the Omniverse allows users to move in reality with their movements translated into the environment, other more common ways of locomotion in Virtual Reality include movement using a controller or users being given the ability to teleport through the environment.

2.4.2 Types of Locomotion Techniques

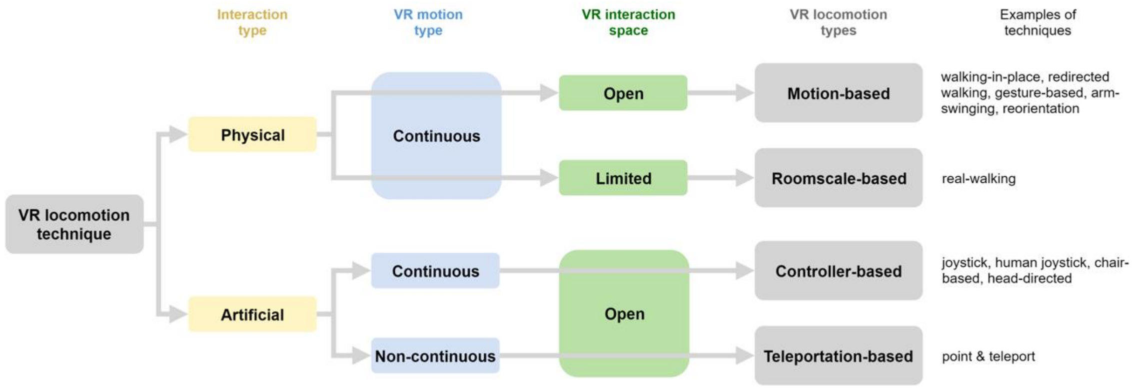

Figure 5 Table of Locomotion Techniques (Boletsis, 2017)

The study 'VR Locomotion in the New Era of Virtual Reality: An Empirical Comparison of Prevalent Techniques' proposes four locomotion types. Most locomotion techniques will fit under one of these four criteria described in the described study.

Motion-based techniques utilise physical movement to move the user in an immersive environment. These techniques will often use input sensors to understand the user's movements and translate them into the immersive space. This can be most observed in devices such as the Omniverse which allows the user to move in reality with their movements being translated into their environment.

Room-scale based techniques utilise physical movements the same way motion-based techniques do. However, room-scale techniques are limited by the size of the physical environment around the user.

Controller-Based techniques require the user to use a controller to move around the immersive environment, the motion is continuous and requires constant input from the user through a controller. Controller types can vary with a simple joystick to keyboards being used for this technique.

Teleportation-based techniques require the user to be teleported in other ways 'jump' to a specific location in the environment. The user will not feel the movement happen and instead the environment will fade to black during the jump.

2.5 User experience and locomotion

Locomotion techniques may have varying effects on user experience in the immersive environment, this section will discuss current research addressing the differences that locomotion techniques may have on user experience.

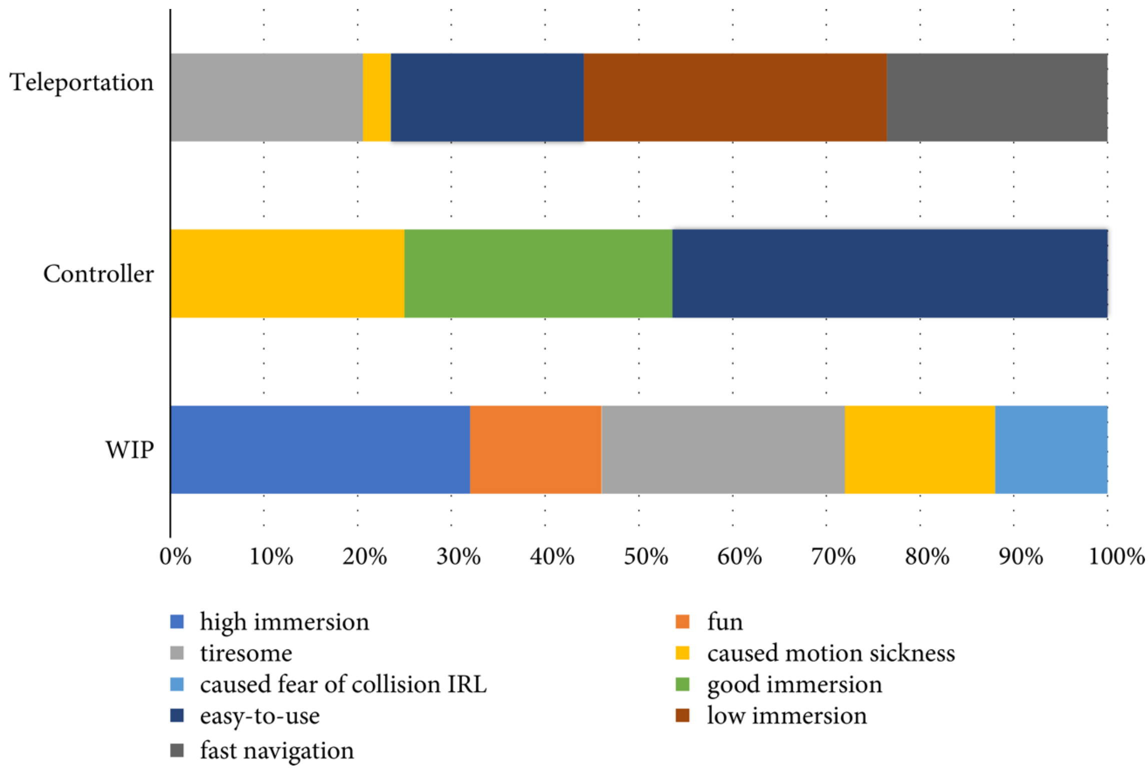

Figure 6 Effects of locomotion techniques on user experience (Boletsis and Cedergren, 2019)

Another study titled 'VR Locomotion in the New Era of Virtual Reality: An Empirical Comparison of Prevalent Techniques' (Boletsis and Cedergren 2019) explored how different locomotion techniques may have a different impact on the experience of users, the study found that some techniques may cause less enjoyment, immersion or feel motion sickness more than other methods (Figure 5). Understanding how different locomotion techniques affect the user's experience are crucial when developing immersive experience, if a learning experience causes cyber-sickness, also known as motion-sickness, easily or is tiresome to use it is to be expected that users may not want to participate in the experience due to the low reward compared with the risks. Game companies and developers must keep in mind the benefits and risks of every locomotion technique and understand fully how their implementation can affect and change an immersive environment.

Wiedemann et al. (2020) explores additional influences of locomotion on user experience with a study involving 89 participants undergoing testing through various locomotion methods, one group of participants involved the use of a gamepad to navigate around a space, with users reporting the experience “difficult” and even “obstructive” causing a decrease in the ease of use, however, this could be explained with many participants having never used a gamepad prior (Wiedemann et al. 2020). When participants experienced real walking in the immersive environment many have described it as “intuitive” “realistic” and “freeing” many others voiced concerned on tripping over cables in the real space (Wiedemann et al. 2020), increasing fear of collision, however, also increasing the ease of use and the presence inducing aspect. Teleportation in the study was described by most users as “easy” “fun” “convenient” and “fast” allowing for swift, fun and easy movement around the space. Users additionally positively reported the ability to get to where they want to be in the space in a fast and efficient manner. Despite the positive feelings experienced by many users on teleportation, some users reported the technique to be “less immersive” “unrealistic” and sometimes even “disorientating” (Wiedemann et al. 2020). Lastly participants were asked to try the treadmill locomotion technique, with many users reporting it as “fun” “intuitive” and even “natural” and one participant stating that the technique feels the close to walking. Although the treadmill received positive comments, the majority of participants described issues about the device and it’s implementation, such as the surface being “slippery”, “insecure”, and even feeling “dangerous”, other participants additionally reported the treadmill as “unrealistic” and lacking in immersion. Interestingly the forward motion of the treadmill was a prominent and obstructing issue for some participants, with the inability to move backwards strongly impacting the enjoyment of the experience, lastly a quarter of the participants have felt the locomotion technique lacked precision (Wiedemann et al. 2020).

Table 2. Comparative table between the different locomotion techniques identified in the reviewed papers

	Presence in the VE	Ease of use	Control precision	Spatial orientation	sations Self-motion	Tiredness	Motion Sickness	VE Adaptation for	s Adaptation to VR
Real walk	++	++	++	+	++	++	++	--	++
LazyNav	+	-	--	+	+	+	--	+	-
Arm Swinging	++	+	-	+	+	-	--	-	--
Walking in place	+	++	+	+	+	-	-	-	+
Teleporting (Hand Gestures)	++	+	++	-	-	++	++	++	-
Human Joystick	+	-	+	+	-	+	--	+	+
Body leaning (Stand position)	+	+	-	+	+	+	--	+	-
MuvMan	+	-	-	+	+	+	-	+	-
Shake your head	-	-	-	+	+	+	-	+	-
NaviChair	+	-	-	+	+	+	-	+	-
Swivel	+	-	-	+	+	+	-	+	-
Redirected Walking	-	+	-	+	+	-	++	+	+
Intuitive striding unit	+	+	-	+	+	+	--	+	--
Body leaning + Joystick	+	-	+	+	+	+	-	+	-
Virtusphere	+	--	--	+	+	--	+	+	+
VibroSkate	+	-	-	+	-	+	--	+	+
Stepper machine	+	-	+	+	+	--	-	+	-
Omnidirec-tional treadmill	++	-	+	+	++	-	+	+	++
Joystick	+	++	++	++	--	++	--	++	-
Teleporting (HMD Controllers)	++	++	++	-	-	++	++	++	+
Accelerator pedal	+	-	-	+	-	-	-	+	+
World-In-Miniature	+	-	-	+	-	+	+	+	+

Figure 7 Comparative table between different locomotion techniques (Cherni et al. 2020)

A study titled ‘Literature review of locomotion techniques in virtual reality’ (Cherni et al. 2020) explored the different locomotion techniques used from 2012 to 2019, identifying and comparing 22 locomotion methods found in 26 research papers. Figure x presents the table created by this study, giving an overall comparison on the most used locomotion techniques and their effects on user experience compared to eachother. This research presents the challenges of locomotion in Virtual Reality and the varied effects different techniques may have on users. For example, in figure x, it is clear that the Joystick techniques excel in ease of use, control precision and cause little to no tiredness, meanwhile it does not excel in areas such as motion sickness, showing the challenging nature of locomotion techniques and their influence on user experience. It is crucial to note that figure x only compares these locomotion techniques to each other, this study presents some limitations such as not all techniques being compared to one another and lack of information with newly developed techniques such as the omnidirectional treadmill (Cherni et al. 2020).

As locomotion techniques develop over time their effect on user experience will change drastically making it difficult to compare and understand the exact differences that each locomotion technique has on user experience compared to each other, research has also been found to often contradict itself with many techniques being used in different settings and different manners making it difficult to fully understand all the locomotion techniques and their impact. The studies present how important locomotion techniques are and how crucial it is to understand the current presumed effects that they have on user experience to develop immersive, fun and fulfilling immersive experiences for users.

2.5.1 Common Challenges of Locomotion on User Experience

Locomotion does not come without its challenges, as described in chapter 2.3.3, locomotion has varied effects on user experience. This creates challenges when developing content for Virtual Reality system, special care must be taken to ensure that the experiences are as accessible as possible to users. It is crucial for developers to understand the challenges that can be encountered when developing Virtual Reality experiences to be able to address these challenges effectively. This section will describe the known challenges of locomotion to further understand the current challenges faced to develop more accurate teaching material in the virtual environment.

2.5.1.1 Cyber-Sickness

Cyber-sicknesses, also known as motion-sickness, is one of the biggest challenges that can be experienced in locomotion (Caserman et al. 2021), cyber-sickness often occurs when disparity between motion, visual and vestibular stimuli, this occurs when the inner ear and the eyes send different stimuli to the brain. Research has been advancing the way we develop locomotion and how locomotion can be improved to create a more user-friendly experience causing less cyber-sickness and allowing for more accessible experiences. Due to this it is more important than ever for designers to understand locomotion fully and can implement these techniques in the best manner possible. Locomotion has the power to greatly change user experience in an immersive environment and in some cases can even render the environment unusable if the probability of cyber-sickness is too high.

2.5.1.2 Tiredness

Tiredness is often a challenge experienced with Virtual Reality headsets that require an input of movement from the user, such as arm-swinging, omni-directional treadmill, and walking in place (Figure X) are known to cause an increase in tiredness. An increase in tiredness can hinder immersive experiences causing users to be unable to participate in the experience for longer amounts of time as well as require more frequent breaks.

2.5.1.3 Ease of Use

The ease of use can be heavily impacted by the locomotion technique used, for example the Omni-directional Treadmill has been reported to have a negative effect on the ease of use (Cherni et al. 2020) with Wiedemann et al. (2020)'s study also reporting treadmill locomotion to have been difficult to use by participants with participants reporting the technique as "slippery". Additionally Boletsis and Cedergren (2019) in their studies reported the walk in place method to have a low ease of use. Ease of use can often be explained by lack of experience with a certain locomotion technique Wiedemann et al. (2020), however, sometimes it ease of use may be low even when a user's experience and knowledge on the technique is high.

2.5.1.4 Low Control Precisions

Low control precision can cause the player to struggle to move accurately in the direction the wish, causing difficulties with navigation in the immersive environment. Low Control Precision can be seen often in the treadmill locomotion technique where users often reported low precision because of the treadmill mechanics requiring users to rotate on the treadmill 180 degrees that often registered as walking forwards Wiedemann et al. (2020). In contrast high precision can be seen in techniques such as teleportation where the user can precisely and accurately point to the area that they wish to move to.

2.5.1.5 Fear of Collision

Fear of Collision describes the fear of colliding into an object or tripping over an object in the real space while being immersed in the Virtual Reality system. For example individuals often experience fear of collision when using locomotion techniques such as the walk in place method, where users may worry about stepping out of the zone and colliding with objects, meanwhile the controller techniques causes no fear of collision as there is no way a user can collide with an object in the real space (Boletsis and Cedergren 2019).

2.5.1.6 Low Immersion

Certain locomotion techniques can summer from low immersion also known as the presence in the virtual environment (Cherni et al. 2020), the walk in place technique can often induce low immersion as users imitate walking in the virtual environment without actually walking in the real space in addition with the difficulty of the gestures required for the method (Cherni et al. 2020). Additionally, techniques such as the teleportation technique may reduce a user's sense of immersion due to the lesser continuity of motion (Bowman et al., 1997), however, teleportation with hand gestures have been shown to increase immersion (Cherni et al. 2020).

2.5.1.7 Low self-motion sensation

Self-motion sensation describes how much the user feels that the movements performed in the virtual environment are their own (ie. Sensation of controlling the movement) (Cherni et al. 2020). For instance the real walk technique increases a user's self-motion sensation, this may be explained by the required realistic movement in the physical space. In contrast the joystick technique caused little self-motion sensation compared, potentially explainable by the lack of realistic movement done by the user in the technique.

2.5.1.8 Low Spatial Orientation

Spatial orientation is the ability for the user to position themselves accurately in relation to the objects and environment around them. This can vary greatly with each locomotion technique due to the immersive nature of Virtual Reality itself. Notably the joystick method causes better spatial orientation than teleporting with hand gestures with teleporting with HMD controls also causing low spatial orientation.

2.5.1.9 Enjoyment

Enjoyment of locomotion techniques is an essential component of design, if users do not enjoy moving around a space they can potentially decide to not continue the immersive experience. Enjoyment can greatly differ based on the locomotion technique used in an experience, techniques such as the walk in place method can be seen as more fun over methods such as the joystick method (Boletsis and Cedergren 2019). Additionally a method such as teleportation was seen as fun by participants (Wiedemann et al. 2020).

2.5.1.10 Discussion

The above section has discussed and identified the the impact of locomotion on user experience, discussing the challenges, benefits and setbacks explored through research of different locomotion techniques. Additionally the chapter has discussed the great importance locomotion techniques can have on user experience potentially rendering immersive experiences unusable in certain cases. Moreover it is clear from research that locomotion techniques can impact aspects of user experience such as enjoyment, immersion, ease of use, cyber-sickness, spatial orientation, control precision, fear of collision and self-motion sensation, increasing the importance of careful consideration and the importance of knowledge on the techniques and their effects for developers. Considering the importance of locomotion techniques on user experience and the significant effect they may have it is clear that teaching future game developers locomotion techniques and their impact on user experience is an essential part of learning to develop good immersive experiences.

2.6 Common Locomotion Techniques

Locomotion has been done in many ways with new techniques being developed through research. Some techniques have been refined and incorporated into commercial Virtual Reality systems such as point-and-click teleportation, which allows users to point to an area inside of an experience and be teleported there, has been widely used in systems such as Oculus Rift and HTC Vive (Boletsis and Cedergren 2019). Other forms of navigation such as walking in place to move yourself in an immersive environment have improved immensely and can be seen in commercial devices (Boletsis and Cedergren 2019). One example of this can be seen in the Omniverse which allows for users to walk on a treadmill with the help of specialised shoes which translates the user's real movements to a virtual environment. This section will describe in depth the most common ways of addressing locomotion in Virtual Reality experiences as well as their specific impacts on user experience.

2.6.1 Point-And-Click

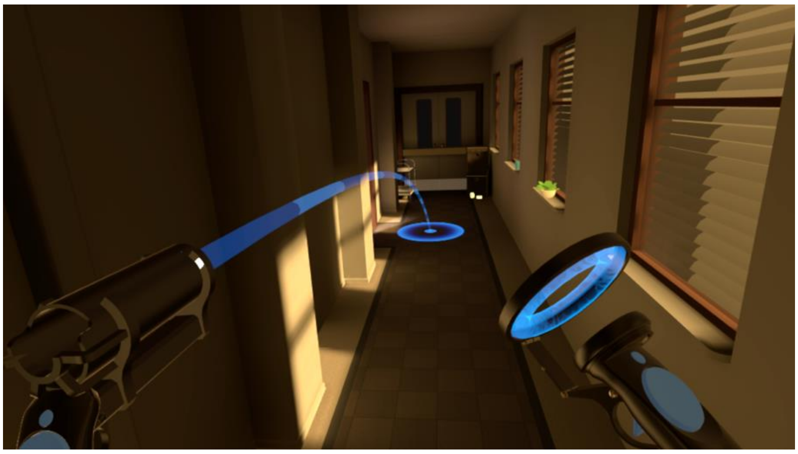

Figure 8 (Carbotte, 2016)

The point-and-click technique also known as teleportation in locomotion is one of the more used and well-known locomotion techniques in Virtual Reality. Using this technique, a user points to an area in an immersive environment and is then teleported to this area. The advantage of this technique is the lesser risk for cyber sickness as the user does not experience any motion when being transported from one area to the next. This technique is becoming one of the most prominent ways of of locomotion in Virtual Reality, this method greatly reduces the risk of motion sickness and does not require a larger physical area (Riecke et al, 2018). Research has also shown that point-and-click is a user-friendly technique that users find fun to use in the experience (Boletsis and Cedergren 2019). While point-and-click has many advantages it does not allow developers to move a user through an environment in a linear fashion. Additionally, this technique can be seen as less immersive to the player than more involved techniques, however, in research it has been found to cause the least cyber-sickness compared to walk-in-place and controller/joystick techniques (Cherni et al. 2020).

Figure 9 Omni-directional treadmill (Robertson 2020).

2.6.2 Omni-directional Treadmill

This technique is rarely used as it requires a virtual reality system that is equipped with the hardware to provide a physical space to walk in, the omni-directional treadmill. The benefit of this technique is the full immersion a user can feel when inside the immersive space with the ability to walk in the same manner as the real physical space. This technique however suffers from weaknesses, one being the cost of a system that can use this technique, not many consumers will have the space and finances to purchase the machine required to be able to use this technique (Calandra et all, 2018) (Warren & Bowman, 2017). Another great weakness is the inaccessibility of this technique for people who may be unable to walk, excluding a wide range of people from participating in the immersive experience. Walking in place can also increase tiredness and has been found to be the most challenging technique to use for participants in studies but has been found to also be the most immersive compared to teleportation and the controller/joystick technique. (reference) Walking in place has also found to be beneficial as it reduces the need for space (Cherni et al. 2020), however, the technique requires safety procedures to ensure that the user does not walk in reality while attempting to walk in the immersive environment itself.

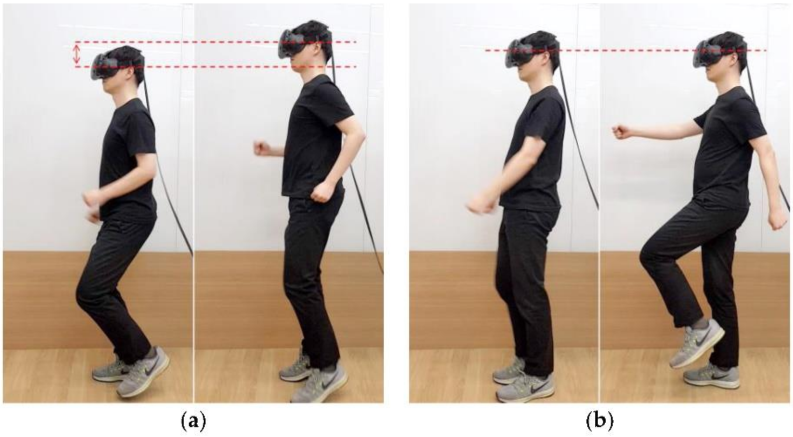

Figure 10 User performing the walk-in-place method (Lee et al. 2018)

2.6.3 Walk-in-Place

The Walk-in-Place technique encourages users to use their whole body by imitating walking without moving forward. This differs from the Omni-directional treadmill by requiring less space and causing less tiredness than moving on the treadmill (Cherni et al. 2020). The user is commonly attached to sensors which can detect the user moving in place and in return translate it into the experience, this provides users with a realistic walking experience in the environment, however, this technique does come with it's challenges. Walk-in-Place may not always be appropriate for an experience, for example in experiences where a user is flying a spaceship it would not be realistic for the user to walk to move the spaceship. Another challenge is the tiredness that can be caused by this technique, while this technique is known to cause less tiredness than the Omni-directional treadmill it still has been shown to cause tiredness compared to other locomotion techniques such as the Controller/Joystick technique.

2.6.4 Real-Walking

During the Real-Walking technique the user can walk in a limited physical space, the user's position is determined by the orientation usually by the HMD's position or the user's limb movements (Boletsis 2017). This technique allows for an authentic walking experience most close to reality, being the most realistic locomotion technique available on the market.

The Real Walking method has been actively developed with TektonGames (2016) creating a new system titled WalkAbout, allowing a user to walk in the game's environment with a limited amount of space. This system allows users to look in the direction that they wish to move in and by holding down a button on the controller enter the WalkAbout system, once the system is started the virtual world becomes blurred to avoid the risk of cyber-sickness and prevent disorientation that the user may feel. In the WalkAbout mode the environment will shift to allow the user to walk again in the environment. This system also features warnings to the player if the user turns around a certain number of degrees to prevent the tangling of the cord and therefore increasing safety (TektonGames, 2016). The WalkAbout method has many advantages, one being the increased safety and the avoidance of cyber-sickness allowing more users to be able to experience this method, however, the WalkAbout system does not address the accessibility for players who may be unable to move and walk around the environment.

While Real-Walking allows for an authentic experience most close to reality, it is not always the solution to Virtual Reality experiences.

Figure 11 Controller/Joystick locomotion (Carbotte 2018)

2.6.5 Controller/Joystick

The controller/joystick technique allows the user to use a controller, joystick, or keyboard to move around the immersive space. This technique closely resembles standard movement in non-Virtual Reality games. This technique is simple to develop and use making it very accessible for developers, however, it lacks the immersion and can be prone to causing cyber sickness in individuals. It is crucial to note that the controller/joystick method has been found to cause the least negative effect and tiredness in studies compared with the teleportation and walk in place techniques, however, it has been found to cause the most cyber-sickness (Boletsis and Cedergren 2019).

2.6.6 Gesture-Based

The gesture-based technique allows for the user to move around the space using gestures. These gestures can range from tapping to pushing and can be tracked by input devices such as the Leap Motion and Microsoft Kinect translating the inputs into motion in the immersive environment (Cherni et al. 2020). Gesture-based movement can be beneficial due to its immersive nature but ease of use with many commercial Virtual Reality headsets, however, this technique still suffers from issues with accessibility for individuals who may be unable to perform the gestures required by the environment.

Figure 12 Automated locomotion (Carbotte 2018)

2.6.7 Automated Locomotion

Automated locomotion allows the user to move through a virtual environment without the use of any controls, the user is unable to choose where they can move to and are only allowed to look around the space. This system can be seen in games such as Pistol Whip (Cloudhead Games, 2019). Research has shown that automated locomotion suffers from less cognitive overload than other forms of locomotion, however, research on automated locomotion is lacking with the least exploration done compared to other locomotion techniques (Martinez et al. 2022).

2.6.8 Discussion

The section above showcases the varied range of locomotion techniques additionally discussing their benefits and setbacks. Additionally the broad range of different locomotion techniques has been presented. From the research reviewed and discussed it is clear that there is a wide range of locomotion techniques each with their specific setbacks and drawbacks that are essential to understand when developing an immersive experience for Virtual Reality further showing the importance of developing teaching tools for students that accurately teach locomotion techniques as well as their features, drawbacks, advantages and effects on user experience.

2.7 Teaching Frameworks

This section discusses frameworks that have been developed to use in teaching content in Virtual Reality. As this thesis will focus on teaching university students' locomotion techniques in Virtual Reality it is vital to discuss and understand the current teaching frameworks to be used in this process in order to create the most effective learning experience possible.

2.7.1 Meaningful iVR Learning Framework (Mulders et al. 2020)

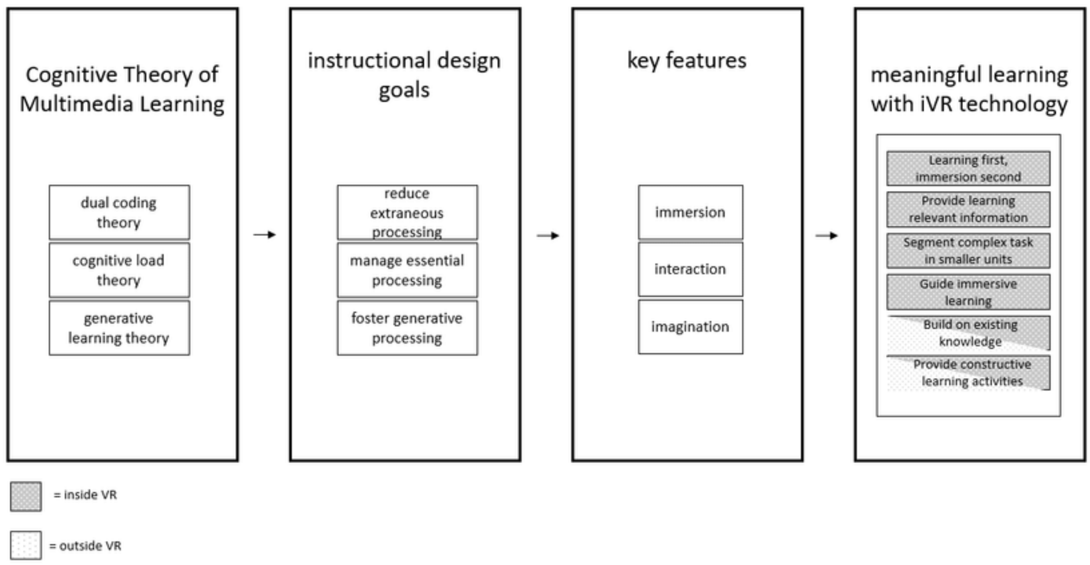

Figure 13 The Meaningful iVR Learning Framework Diagram (Mulders et al. 2020)

The Meaningful iVR Learning Framework (Mulders et al. 2020) has been developed to combat the lack of instructional concepts for Virtual Reality in learning environments. Moulders et al. (2020) states that there is very little information on creating meaningful learning in Virtual Reality, and very little is also known on the learning processes occurring in VR environments. In addition the framework argues that 'iVR technology used in educational settings should be designed according principles to design multimedia to benefit from its promising characteristics.' (Mulders et al. 2020). The framework proposes six evidence-based recommendations that should be considered when designing an effective iVR learning environment.

2.7.1.1 Prioritising learning over immersion

Current research presents an unclear picture on the relationship between immersion and learning outcomes, with some studies finding that a higher feeling of immersion can contribute negatively to learning outcomes which is a contradictory picture to the belief that immersion can hugely support learning while others have found immersion to have a positive influence on learning outcomes (Mulders et al. 2020). The framework proposes that learning is to be put first with immersion second, focusing first and foremost on the quality of learning rather than the level of immersion a user feels. For example an experience that focuses mostly on immersion, presence and overall graphical fidelity will achieve worse learning outcomes than an experience that prioritises educational frameworks.

2.7.1.2 Provide learning relevant interactions

Mulders et al. (2020)'s framework states that interactions performed in the iVR should be relevant to the learning itself through physical activity. It is crucial to note that this aspect of the framework is only relevant when the iVR is used to teach skills that can be replicated in a Virtual Environment, for example to teach cooking a user could re-enact the same movements required. The framework also stresses the importance of avoiding learn-irrelevant interactions and encourages for learners to undergo pre-training to have a good foundation on the basic concepts and the usage of iVR controls.

2.7.1.3 The importance of segmenting tasks

iVR learning environments have a high risk of overhelming learners (Mulders et al. 2020). This can cause lesser learning outcomes and cause on obstacle in teaching using iVR. The framework presents how crucial it is to create segmented lessons with summarizing phases after each in iVR and avoid long bursts of complex tasks that are likely to overhelm the learner and decrease the learning outcomes (Mulders et al. 2020).

2.7.1.4 Guiding immersive learning

Guidance in iVR is crucial to a smooth and productive learning environment. Studies has shown that lack of guidance causes learners to feel overhelmed and struggle to learn from the iVR experience (Mulders et al. 2020). Guidance can be provided in many ways from providing hints and information during the experience to using voice overs guiding learners through every stage of the learning environment.

2.7.1.5 Building on user's prior knowledge

Learning experiences in iVR should be tailored to the level of knowledge the learner has on the topic. Failing to do this can cause the learner to feel under- or overstimulated (Mulders et al.

2020). Mulders et al. (2020) also states that ‘worked examples and tutorials may help learners with a low level of prior knowledge, but hinder learners with a high level of prior knowledge’ making it crucial to create an environment that is accessible and usable by people with all levels of knowledge. It is especially vital that learners with prior little knowledge are provided support in the experience to avoid cognitive overload and in return the decrease of learning outcomes (Mulders et al. 2020).

2.7.1.6 Providing the user with constructive learning activites

Providing learners with constructive learning tasks is essential to promote learning in the iVR experience. Learners who engage with a iVR learning experience but have no learning activities available will perform worse than users who were provided with such learning activities. It is vital that learners can immerse themselves in the experience as much as possible through performing activities that connect to the topic being taught at hand, ‘even the most impressive, immersive and realistic iVR environment will not promote learning if learners do not engage in learning activities’ (Mulders et al. 2020).

2.7.2 Fowler’s (2015) improved framework for teaching in Virtual Reality

Virtual reality and learning: Where is the pedagogy? (Fowler, 2015) discusses the lack of usage of models when developing experiences for Virtual Reality as well as the lack of frameworks for teaching in Virtual Reality, and in return proposes an improved framework to be used when developing teaching tools for Virtual Reality. This framework expands on Dalgarno and Lee’s (2010) model and offers a new approach to be used in teaching for Virtual Reality. It offers a range of considerations to be used in development to increase learning outcomes in learners.

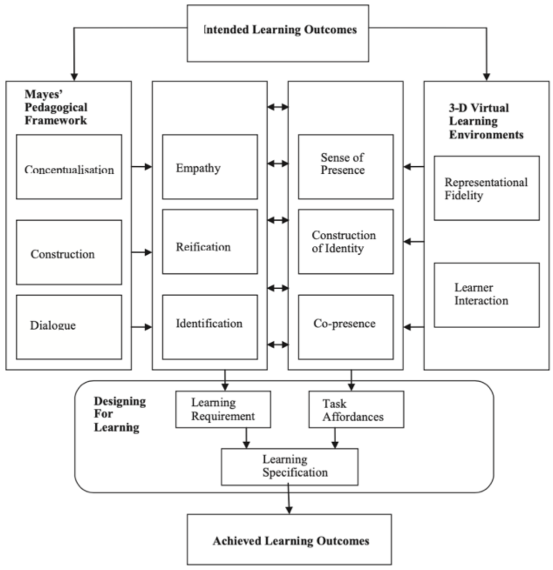

Figure 14 Improved model for learning in 3D VLEs (Fowler, 2015).

The framework above (Figure 7) is an improved model of learning in 3D VLEs (3D Virtual Learning Environment), the model describes the various considerations that should be considered when developing learning experiences for virtual environments.

Conceptualisation refers to the learner understanding the concept that will be taught in the experience, for example the experience should present to the learner what will be taught, in the instance of this Thesis this could mean teaching a student what locomotion is and explanation the locomotion techniques that exist. After the learner is given the understanding of the concept the experience moves onto construction, during this process the learner performs tasks such as writing an essay or a laboratory study. Through this the learner can experience and understand the concept. Dialogue, being the last step of this process, describes the learner testing their understanding through interaction and discussion with others, through doing this the learner can reinforce their understanding of the topic at hand. These three learning stages can be associated with different types of immersion experiences known as conceptual, task and social immersion, these types of immersions interact with the technical emerging properties of 3-D VLEs (Fowler, 2015). Fowler (2015) proposes three terms on par with Dalagarno and Lee's 'Construction of identity' 'sense of presence' and 'co-presence' to instead describe conceptual, task and social immersion to avoid confusion with technological immersion. These terms are as follows 'empathy' 'reification' and 'identification', empathy describes the need to emphasise and identify with the concept being taught to understand it, reification focuses on making the concept clearer and concrete to the learner, which is an essential part of task immersion, while identification depends on learners having a deep understanding of concepts to allow them to engage in discussion on the topic.

Sense of presence describes the sense of being there in an environment, in a multi-user environment this is called co-presence and is directly affected by representational fidelity and learner interaction. Representational fidelity describes the quality of the display used in the experience, for example if the experience is realistic or photorealistic, if an experience has high fidelity that signalises that the experience is highly realistic. However, this does not only apply to the graphical fidelity of the experience but can also apply to the consistency of object behaviour.

Construction of identity describes to which extent the user can identify with the experience; this is usually affected by learner interaction which describes the interaction available resulting from the degree of embodiment. In 3-DLEs embodiment is found using avatars, this avatar is responsible for the user's representation through the ability to control, create objects and communicate.

It is crucial to understand that these three user experiences are not required in a learning experience, and it is unclear how much these experiences contribute to learning outcomes in 3-DVLEs. Not all learning environments will require the use of an avatar and there may be cases where the use of an avatar is detrimental to the learning environment. For example, in locomotion if a learner is learning about the rail movement technique, the use of an avatar is not required. It is crucial for the practitioner to consider which aspects of the model apply to their specific learning environments and goals as there may be circumstances where parts of this model are not required or beneficial.

Learning requirements are best described as generic learning activities based on Bloom's (1956) taxonomy (Fowler and Mayes, 2004). These learning activities can be seen inFigure 15..

Table 1: Deriving learning activities

Learning stage (based on Mayes & Fowler's, (1999) framework)	*Learning outcomes/ objectives (based on Bloom's [revised] taxonomy)*	*Learning activities (based on Conole et al's, (2004) mini-learning activities)*
Conceptualisation	Exposing learners to new concepts, theories and facts	Receiving information, scoping domains, identifying boundaries, generalising from given facts
	Gathering facts/concepts	Gathering resources, brainstorming a concept, discovering facts, interpreting facts, classifying facts
	Presenting and explaining facts or concepts	Ability to organise and present material in a timely, logical and coherent way
Construction	Evaluating facts/concepts	Developing values, synthesising of key findings from a range of resources, ranking and rating a set of values, making judgements, making comparisons, interpreting facts, recognising subjectivity
	Building/testing/applying theories/concepts	Recognise patterns, draw conclusions, predict outcomes, construct models, follow instructions, apply knowledge, demonstrate outcomes, plan experiments, state rules
	Solving/analysing problems	Investigate a problem; analyse wholes into parts; synthesise parts into wholes; apply principles; select effective solutions; use methods, concepts, theories in new situations
	Acquiring skills	Sequence parts, practice sequences
	Acquiring and applying knowledge to perform in real world settings	Observing, analysing and reflecting upon other people's real world behaviours and then practicing those behaviours in real world settings
Dialogue	Reflecting critically	Self-assessment of level of competence, critique own performance, recognise own limitations
	Engaging in discussion	Defend a position, set up teams of learners, establish different roles in a team, discussion, share ideas and come up with a combined list

- Locus of control (the teacher or learner?)
- Group dynamics (individual or group?)
- Teacher dynamics (one to one, one to many, many to many?)
- Activity or task authenticity (realism?)
- Level of interactivity (high, medium or low?)
- Source of information (social, reflection, informational, experiential?)

Figure 15 Deriving learning activities (Fowler, 2015)

Figure 8 provides learning stages, outcomes and potential learning activities alongside questions help configure the most effective teaching and learning approach to be used. Using this figure the practitioner is able to create the most useful teaching and learning experience for the learner, for example some tasks may need a low level of interactivity or may be individual tasks instead of group tasks in which co-presence is not necessary and dialogue may not be always useful. It is crucial to consider every aspect of the model to create the approach that is most effective for the topic being taught.

The learning specification (Figure 7) is created from combining learning requirements and task affordances.

The five affordances or benefits are spatial knowledge representation, experiential learning, engagement, contextual learning, and collaborative learning. These five affordances directly translate into learning benefits (Fowler, 2015). The usage of this model can heavily impact the learning outcomes in 3-DVLEs, hugely improving the value of learning environments.

Fowler's (2015) improved model is a hugely detailed and beneficial framework in assisting with the creationg of 3-DVLEs. However, this model has some drawbacks, it is important to consider how the lack of usage of such models may be down to the hugely detailed and complex teaching framework. For example, most research done in Virtual Reality is done by individuals and researchers with very little knowledge on teaching at hand, complex frameworks such as these may be difficult to understand and execute without the proper teaching fundamentals required beforehand. As an example, a computer science researcher may be unlikely to understand the teaching fundamentals and design making this model more inaccessible. For this thesis it is crucial to consider to what extent this model can be implemented in an accurate manner without the need of specific teaching knowledge that is unobtainable within the timeframe.

2.7.3 Discussion

In this section two frameworks developed for teaching in Virtual Reality have been discussed and analysed. Firstly the The Meaningful iVR Learning Framework (Mulders et al. 2020) and secondly the Virtual reality and learning: Where is the pedagogy? (Fowler, 2015) framework. The Meaningful iVR Learning Framework (Mulders et al. 2020) provides a good foundation for teaching in Virtual Reality, describing the six crucial aspects to consider when developing a learning experience for Virtual Reality. However, The Meaningful iVR Learning Framework fails to address more complex teaching theories unlike Fowler's (2015) framework which refers to Bloom's revised taxonomy (2001) amongst other frameworks. Fowler's (2015) framework combines multiple frameworks creating a new specialised advanced framework for teaching in Virtual Reality, this framework provides more complex and specific considerations for developing teaching tools in Virtual Reality. Additionally, Fowler's (2015) framework contains more specific learning activities and stages of learning compared to Mulders et al.'s (2020) Meaningful iVR Learning Framework. Despite these advantages, Fowler's (2015) framework can be considered too complex to implement fully in the time scope available in this thesis, additionally the framework discusses complex teaching methodology that may not encourage inter-disciplinary use and require prior teaching knowledge to implement correctly. With consideration to the discussed advantages and disadvantages of the two frameworks this thesis will combine both Fowler's (2015) with Mulders et al's (2020) framework in order to create a clear but specialised framework that can be implemented and used correctly in the scope of this thesis and inter-disciplinarily in future research.

2.8 Discussion of Literature Review

The following discussion will summarise discussions in the literature review as well as define the thesis and justify decisions made during the literature review.

This literature review has defined what Virtual Reality is, Virtual Reality systems, locomotion techniques, locomotion techniques' impact on user experience as well as two teaching frameworks used for developing teaching content for Virtual Reality. Furthermore, the literature review has highlighted and addressed the lack of accessible teaching tools in Virtual Reality and the lack of research in this area, in addition the literature review has also addresses the importance of locomotion techniques and their impact on user experience, stressing the importance of teaching future developers the impact of locomotion techniques on user experience due to the heavy impact they may have on users in Virtual Reality. Lastly the literature review has also discussed the benefits of teaching in Virtual Reality resulting in potentially higher learning outcomes. This thesis will use the Meta Quest 2 as well as Google Cardboard because of its previously discussed accessibility compared to other Virtual Reality systems such as the PlayStation VR and the Omni-directional treadmill. The use of Meta Quest 2 and the Google Cardboard allows for the most accessible teaching experience which directly addresses the lack of accessibility in current Virtual Reality teaching materials. Additionally, to support accessibility Mozilla Hubs will be utilised to create an immersive teaching experience, keeping in consideration the scope and time for this project the pre-build aspect of Mozilla Hubs allows for more focus on the implementation of the teaching framework in the time required compared to Unreal Engine, which requires the development of an environment from scratch. Secondly Spatial.io, another platform discussed in the literature review, lacks the required compatibility with mobile powered Virtual Reality headsets such as the Google Cardboard. Furthermore, a framework will be constructed using both Fowler's (2015) and Mulders et al's (2020) teaching frameworks for Virtual Reality, to create a new but specialised framework that can be implemented and used accurately in the scope of this thesis and inter-disciplinarily in future research addressing the lack of teaching frameworks for Virtual Reality teaching. Using the decisions made in the literature review an accessible teaching tool will be developed for Virtual Reality using the constructed framework derived from Fowler's (2015) and Mulders et al's (2020) frameworks for Virtual Reality. This accessible tool will educate students on the differences between locomotion techniques and their impacts on user experience using the research discussed in the literature review, addressing the lack of teaching Virtual Reality in the system itself as well as addressing the lack of accessibility in Virtual Reality teaching tools. Additionally, the thesis will address the lack of use of the use of frameworks in teaching in Virtual Reality through the developed tool.

Chapter 3 Methodology

3.1 Introduction

This chapter will explain the methodology undertaken in the study; the methods used to achieve the research objectives, this methodology will include the proposed framework, research philosophy, design choices, ethical considerations, data collection methodology and limitations of the research.

The primary focus of this research is to identify and understand the effects that teaching Virtual Reality locomotion techniques in Virtual Reality has on University Students. This will be done through the creation of a immersive space in Virtual Reality using a newly created framework combined from frameworks created for teaching in Virtual Reality. The space will then be tested with University Students studying Game Design and feedback will be taken to understand the effects that teaching Virtual Reality in the system itself have on University students.

3.2 Research Design

The following chapter will outline, justify, and discuss the research philosophy, type, strategy, time, sampling strategy and data collection methods.

3.2.1 Research philosophy and time horizon

Research philosophy is a crucial component of research, a research philosophy identifies underlying beliefs of the research itself. Interpretivism, one of the main research philosophies, assumes that the reality is unique to each observer. This research philosophy assumes that every participant taking part in the study will have their own perspective with no single shared reality (Ritchie and Lewis 2003). As the study involves participants experiencing a Virtual Reality learning environment, every participant may have a different opinion on the environment and the level of learning they feel they have obtained through the experience may differ. Hence, this study aligns with the interpretivist perspective, which permits the use of qualitative data collection methods to obtain participants' more comprehensive views on the experience. Interpretivism additionally allows for the usage of qualitative data collection methods, allowing for participants to express more detailed opinions on the experience. Therefore, this thesis has mainly used the interpretivism research philosophy when undertaking the study, developing data collection, and discussing the results of the thesis.

The study has been performed in a cross-sectional time horizon. This meant that data was collected at a single point in time. This offered a snapshot of the participants' perceptions, attitudes and experience regarding the VR experience. Since the primary focus is on assessing the immediate effect and impact of the VR experience, a cross-sectional approach was the most suited for capturing these perceptions. As the study is focusing on understanding the immediate impact of the VR experience rather than tracking changes over time over a long period, the cross-sectional time horizon made the most sense in the study.

The study incorporated quantitative methodology such as the Likert Scale survey in order to measure participants' perceptions of the Virtual Reality (VR) teaching experience and its impact. Likert Scale surveys provide a structured format for respondents to express their opinions on a graduated scale, allowing for a quantitative assessment of attitudes and preferences. This approach enhances the clarity and precision of the gathered data, enabling the study a more in depth understanding of participants' views on the immersive experience. The utilization of Likert Scale surveys aligns with the established research methodologies for its reliability in measuring attitudes and perceptions (Likert, 1932; Carifio & Perla, 2007). This methodological choice strengthens the study's ability to draw meaningful conclusions about the perception of the VR immersive teaching experience.

3.2.2 Data Collection

The data in the study was obtained through semi-structured surveys using the Jisc platform which participants were invited to fill out after using the immersive environment teaching tool in VR. Semi-structured surveys provided several advantages during the study, a key advantage was the capability for more open-ended questions allowing participants to offer more tailored explanations to their specific experiences. Furthermore, semi-structured Jisc surveys allowed for multiple participants to undertake the survey on different computers, allowing for the study to take place with multiple participants.

The structured surveys was structured around exploring the participants perceptions and opinions on the immersive learning experience compared to traditional teaching methods, including the level of engagement, usefulness and perceived learning competence that the participants have experienced. Participants were additionally asked to compare their experiences in the framework supported rooms to their experience in the non-framework supported rooms allowing the researchers to understand the impact that the framework had on participants.

Participants were be asked to participate from the Game Design course and students outside of the Game Design course were not accepted into the study. The reasoning behind this comes from the concern that none Game Design students may not have sufficient knowledge to understand locomotion techniques. For example, a nursing student may not be knowledgeable on locomotion techniques and therefore their personal experiences may make it difficult to draw accurate conclusions on the effectiveness of the immersive experience.

3.2.3 Open Ended Questions

This section showcases each question in the survey and describes how the question contributes to the research. All participants were informed that all questions apply to framework-based rooms, the first three activity rooms, unless stated otherwise. All replies from participants were regarding the framework-based rooms.

3.2.4 In what ways do you think the virtual reality learning environment supported or hindered your learning compared to traditional classroom methods?

This question offers participants the chance to provide their opinion on the experience compared to traditional classroom methods. This allows the study to understand how participants perceived the experience when compared to traditional classrooms. It is a key question of the study as it relates directly to the learning objective and research question in the study which aims to compare participants' perception of the experience compared to traditional classrooms. Through this question we can understand if the VR experience hindered learning or supported it.

3.2.5 Do you think the virtual reality learning environment is a useful tool for teaching Virtual Reality locomotion? Why or why not?

This question allows the study to understand participants' perception on the experience itself. Through this question the study is able to gain deeper insight and understanding in how participants' perceived the VR learning environment and how beneficial they have found it in terms of learning locomotion techniques. The question additionally asks the participants to state why or why not to deeper understand the effects of the tool on participants.

3.2.6 Is there anything else you would like to share about your experience in the virtual reality learning environment?

This question allows for participants to state any views of the experience they had that do not fit any other question. This allows the study to understand any additional insights or patterns that arise from the research. For example, if all participants state that they experienced pain during the experience due to the headset this provides the study with valuable information into the challenges of using VR as a teaching tool. Participants may also compliment sections of the experience that are not asked for in other questions.

3.2.7 Were there any challenges or difficulties you experienced in the virtual reality learning environment? If so, can you describe them?

This question allows the study to understand and analyse any challenges or difficulties that participants may have encountered during the experience. For example, if participants found the experience confusing to navigate or felt that the hands-on experience decreased their enjoyment of the

3.2.8 In our VR immersive experience, which approach did you find more useful in teaching you about locomotion techniques: the rooms with audio and video materials found at the end of the experience or the two interactive activties allowing you to try the locomotion techniques yourself?

The research objective and question of the research aims to understand how participants perceive framework-based VR experience compared to the no framework VR experience. This question allows us to understand which approach was more useful for participants, therefore gaining insight into how participants perceive the experiences using a framework compared to experiences without.

3.2.9 Why did you find this more useful? What made it better?

This question allows the study to address and understand why participants chosen the approach they have chosen. This gives the opportunity to understand participants' perspectives and why certain approaches felt more beneficial to participants. E.g. a participant may choose the framework approach due to the hands-on experience, this allows the study to understand the influence the framework has had on participants.

3.2.10 Likert Scale Questions

The study contained several Likert scale questions, participants were informed that all Likert scale questions apply only to the framework-based room, participants responses do not apply to the last rooms of the experience which do not use a framework.

3.2.11 I have found the experience to be disorganised or unstructured.

The following question allows the study to understand if the framework functioned correctly in terms of appearing disorganised or unstructured. The frameworks aim is to create an organised and structured experience that ensures participants do not feel overwhelmed. This question is crucial in understanding participants perspectives on the experience, for example, if a participant states the experience was disorganised or unstructured the experience may have been less beneficial for the participant.

3.2.12 I have found the experience confusing to navigate.

This question additionally allows the study to understand if the framework was effective, as components of the framework focus on ensuring the experience is not confusing to navigate understanding if this functioned properly is crucial in evaluating the effectiveness of the framework itself.

3.2.13 I have found the activities useful and helpful in understanding locomotion techniques

This question allows the study to understand how useful and helpful participants have perceived the experience to be. While open-ended questions are crucial in understanding participants experiences, the quantitative nature of the Likert scale surveys allows the study to understand further if participants found the experience useful and helpful in learning locomotion techniques.

3.2.14 I didn't find the 'learn by doing' approach helpful in learning locomotion techniques

The following question allows the study to understand if participants found the hands-on approach helpful, this is crucial as the hands-on experience is a crucial component of the framework itself, specifically the construction phase of the framework. Understanding if the hands-on experience is beneficial is important in understanding if the framework was beneficial to the experience.

3.2.15 Data Analysis

The study used thematic analysis as the chosen qualitative method for the collected data. Thematic analysis, known for its ability to uncover patterns, themes and meanings within qualitative data through systematic coding (Braun & Clarke, 2006), is particularly well-suited for this study. The approach allows the study to explore the participants experiences and perceptions concerning the teaching tool developed in the study. (Clarke & Braun, 2013)

Participants firstly were asked to complete a short survey on the Jisc website. Initially the collected data was read several times to establish a preliminary understanding, laying the foundation for the identification of themes within the answers provided by participants. Following this phrase, the data was coded to allow for the researchers to gain a better understanding of the data.

The next step involved the grouping of these codes into broader, overarching themes, allowing for more comprehensive representation of the data collected, this additionally allows for more concrete conclusions to be made on the data found. The final stage included interpreting the data that has been grouped into themes, in relation to the central research question. (Clarke & Braun, 2013)

In summary, the use of thematic analysis allows for insights into the participants' perspectives on the teaching tool developed in the study better understanding the effectiveness of the teaching tool.

3.2.16 Research strategy

The research will be taking an exploratory stance, by utilising a developed framework composed of other discussed and identified frameworks backed by teaching theory, a study will be undertaken to explore how the framework affects learning competence in university students studying Game Design.

3.2.17 Equipment

- Meta Quest 2
- Mozilla Hubs
- Internet Connection Required

For the study an Meta Quest 2 was utilized with the Mozilla Hubs software. The Oculus Quest 2 was chosen as a cost-effective VR headset that aligned with the research goals and objectives discussed in the research by creating an accessible tool for teaching locomotion techniques. Furthermore, the Meta Quest 2 was chosen based on its ability to smoothly run Mozilla Hubs without significant impediments. This was of high importance in the research lessening the chance that potential disruptions or limitations would not compromise the research.

Secondly Mozilla Hubs was used in conjunction with the Oculus Quest 2 headset for the study. The rationale for selecting Mozilla Hubs is due to its cost-effectiveness and user-friendliness which was crucial for the study. The main research objectives focus on creating an accessible tool so Mozilla Hub's usage was logical based on its free-to-use platform and user-friendliness.

Additionally, Mozilla Hubs integration with the Oculus Quest 2 allowed for easy testing of the immersive experience as well as ensuring a smooth workflow in development allowing for changes to be implemented easily which was critical at all steps during the creation of the tool.

Lastly due to the nature of Mozilla Hubs being a browser based tool, an internet connection was required at all times. A stable environment was chosen for the study in order to ensure the best likelihood of consistent internet connection in order to allow for the most consistent experiences for participants.

3.3 Proposed Framework

Research undertaken in the literature review has shown the lack of a clear and concise, easy to use framework for teaching Virtual Reality concepts in the system itself. This section discusses and combines the Meaningful iVR Learning Framework with Fowler's (2015) Improved Framework in order to create a new, accessible framework. Additionally, this section addresses and solves the research objective "3. Develop an accessible, easy-to-use framework supported by current frameworks identified in the literature review to be used in higher education when teaching locomotion techniques and their impact on user experience in Virtual Reality itself" by creating a framework to be used in experimentation.

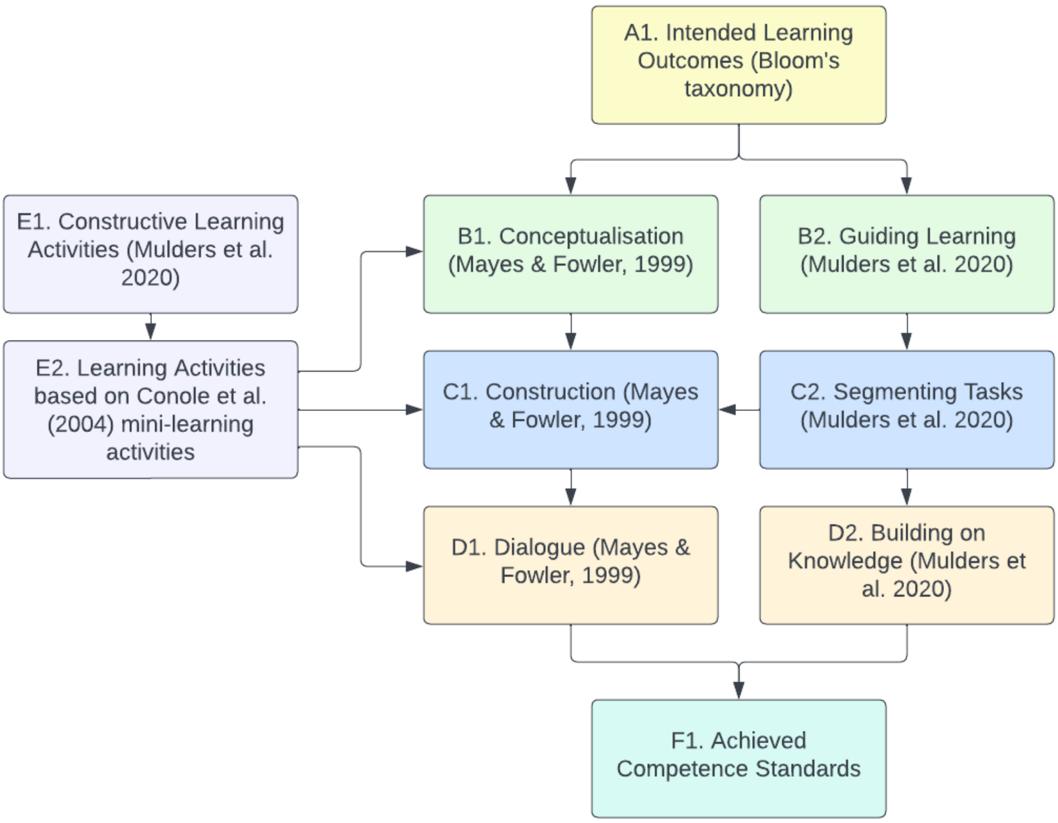

Figure 16 Constructed Framework

Figure 14 presents the proposed framework combined from both Fowler's (2015) Improved Framework with Meaningful iVR Learning Framework. Fowler's (2015) improved framework for teaching in Virtual Reality uses teaching theory with Virtual Reality components in order to create an advanced framework, however the framework fails to be accessible inter-disciplinarily and depends on a good understanding of teaching theory. On the other hand, the Meaningful iVR Learning Framework (Mulders et al. 2020) proposes a more accessible teaching framework, in return lacking the extensive theory that Fowler's (2015) framework provides.

The learning outcomes and objectives are based on Bloom's revised taxonomy (2001) these objectives decide what the aim of the experience is and the end result required from this experience, for example the ability to expose learners to new concepts, solving/analysing problems and acquiring skills (Fowler, 2015). This stage of the framework is crucial, allowing for a clear outline of the experience and it's intended learning outcomes. This stage comes before any other, allowing the teacher to first and foremost plan and address what the experience will include.

Conceptualisation (Mayes & Fowler, 1999) (C1), is a learning stage in which the learner is exposed to new concepts, theories and facts. This can be easily compared with a student being shown a PowerPoint or reading a textbook in a traditional learning environment, during this stage the student is exposed to new information identifying what the student will be learning through the experience. C1 is heavily supported by Learning activities based on Conole et al's (2004) mini learning activities (E1), in which the learner performs activities to support the current learning stage. During conceptualisation the learner can receive information, gathers resources, brainstorms concepts and classifies facts. C1 links closely to Guiding Learning (Mulders et al. 2020) which happens at the same time as Conceptualisation, Guiding Learning requires the learner to be guided through every step of Conceptualisation (Mayes & Fowler, 1999) in order to not overwhelm the learner with new information, concepts and theories obtained during this stage. This component is crucial as it ensures that the learner is provided with a smooth and effective learning environment. Guiding learning can be done in the Virtual Environment through tips, hints and voice overs that address and explain every stage of the experience to the learner.

Construction (Mayes & Fowler, 1999) is the next learning stage in the framework, during this learning stage the learner performs activities to further their knowledge and understanding of the theories and concepts they have been exposed to. This can be compromised of tests, essays and other learning activities. Learning outcomes/objectives (based on Bloom's [revised] taxonomy) provide four objectives/outcomes that can be addressed during this stage, ‘evaluating facts/concepts’ ‘building/testing/applying theories/concepts’ ‘solving/analysing problems’ ‘Acquiring and applying knowledge to perform in real world settings’ (Fowler, 2015). Segmenting Tasks (Mulders et al. 2020) functions at the same stage as Construction (Mayes & Fowler, 1999). Virtual Reality learning environments have a high-risk of overwhelming learners (Mulders et al. 2020), this causes lesser learning outcomes and obstacles in teaching in Virtual Reality. In order to overcome this issue, Mulders et al. (2020) proposes Segmenting Tasks, during this stage the learner is given tasks in short bursts to perform avoiding long complex tasks, additionally the learner is provided with summarizing phases in the experience to aid with learning outcomes. This aspect of the framework improves upon Construction (Mayes & Fowler, 1999) increasing positive learning outcomes in the environment, additionally Segmenting Tasks (Mulders et al. 2020) assists with Learning activities based on Conole et al’s (2004) mini learning activities.

Dialogue (D1) is an essential stage of learning, during D1 the learner is given an opportunity to test their knowledge and understanding through interaction and discussion with peers, through this the learner can reinforce their understanding of what they have learned, during this process a learner can additionally understand the topic better and discuss any components of the lesson that they struggled with. D1 is an essential component of a Virtual Reality learning experience, as it allows for a learner to more deeply understand the topic at hand and solidify their existing knowledge. D1 closely links with Building on Knowledge (Mulders et al. 2020) (D2), D2 describes how the learner uses the experience to build on existing knowledge, stressing the importance of creating an experience that aids both learners with prior experience and without prior experience of the topic at hand.

Constructive Learning Activities (Mulders et al. 2020) (E1) stresses the importance of providing the learner with learning activities in the immersive environment, without learning activities the learner fails to engage with the topic at hand in return decreasing learning competence. Additionally Learning Activities based on Conole et al (2004) mini-learning activities (E2) state the learning activities to be utilized when creating an immersive experience, E2 dictates the creation of the experience and affects every component in the framework becoming the deciding factor of how every component of the framework is executed. As an example, E2 states that during D1 the learner can participate in the following activities “Self-assessment of level of competence, critique own performance, recognise own limitations” (Fowler, 2015) informing how D1 is to be executed effectively.

Lastly the framework concludes with Achieved Competence Standards (A1), while both frameworks discuss learning outcomes and make no mention of A1, Competence standards align more accurately with higher educational institutions. As the aim of this thesis is to develop a framework that is easy to use and accessible for higher education it is certainly more valuable and logical to use the current Competence Standards that are used currently in Higher Education, allowing for better utilisation of this framework in higher educational settings.

Several aspects of the frameworks identified have not been used in the creation of this framework. Prioritising learning over immersion (Mulders et al. 2020) was not included as research is unsure if immersion contributes negatively or positively to learning outcomes (Mulders et al. 2020) for this reason this component may be invalid and ultimately provide no clear benefit to a learner's experience. Secondly Provide learning relevant interactions (Mulders et al. 2020) was not utilized in this framework as this aspect of the framework is only relevant when the iVR is used to teach skills that can be replicated outside of the Virtual Environment, for example cooking, therefore this aspect of' the framework is irrelevant to the study.

The framework components of 'empathy' 'reification' and 'identification' (Fowler, 2015) have been also been omitted from the proposed framework, as the framework aims to be accessible and easy-to-use inter-disciplinarily considerations have had to been made to asses which components of the framework may be too technical or rely on complex teaching theory that would in return create a less accessible and easy-to-use framework. As 'empathy' 'reification' and 'identification' (Fowler, 2015) link closely with the already discussed B1, C1 and D1 they have not been included in the framework in an effort to maintain accessibility. Additionally the three framework components 'Representational Fidelity' 'Sense of Presence' and 'Construction of identity' (Fowler, 2015) are not required when creating an immersive learning experience in Virtual Reality, with research being unclear on how much the components contribute to learning outcomes in immersive learning environments, with unclear and limited research on the benefits of the three components it is understandable that they will not be used in the proposed framework.

3.4 Ethics

The purpose of the following chapter is to describe the ethical considerations that apply to the research project which includes semi-structured qualitative surveys, the aim of this section is to outline the ethical principles and guidelines followed to ensure the protection of participants data, privacy, safety and right additionally ensuring that the research is performed in an ethical manner. Secondly this section will describe and address how data was collected from participants, how informed consent was obtained, how the data was stored and how anonymity of the data was maintained protecting the privacy of the participants.

During the research ethical principles and guidelines were followed to ensure everything was conducted in an ethical and responsible manner. These ethical principles and guidelines are essential in ensuring that the research was conducted in a responsible manner with respects to the dignity, rights and privacy of the participants involved in the study.

Participants were informed of the nature of the study and written informed consent was obtained from all participants, no participants that are unable to provide consent were asked to participate in the study. Participants were provided with a consent form which included information about the purpose of the study including the nature of the study. Secondly, the consent form was provided to participants who felt comfortable in the language of the study, ensuring that the participant comfortably understands the form and the study, participants who did not feel comfortable in the language the study was undertaken in, English, were not asked to participate. Additionally, participants were not asked for their name, personal information and contact details in the consent form. When providing consent participants had to trick a box on the Jisc survey website instead.

Lastly participants were informed that withdrawing out of the study held no penalty and that all information collected during the duration of the study would be kept confidential and fully anonymous, used purely for research purposes. Participants were informed about the withdrawal process, especially informing participants that their voluntary participation could be withdrawn at any point during the study. The aim was to remain transparent with participants, informing them that to withdraw from the study they must not complete the Jisc survey. This approach allowed the participants to have control over their involvement in the research until the moment of submission, giving them agency to withdraw.

The nature of the study was low-risk and followed an anonymous data collection approach, as no personal information was asked for from participants. Given these circumstances it was decided that due to the low risk of the research passwords were not required to keep the data secure. The data mainly resided on the Jisc platform which is the approved and main platform recommended by the University of Hull's ethics team. Using a platform that was directly approved by the university assured for the best data security.

During the preparation for data analysis, the survey data was downloaded directly from the Jisc website. This step was essential in order to import the data into Nvivo, a software also recommended by the University of Hull in data analysis. While it may not always be appropriate to store data files such as surveys on personal computers, the requirements of the Nvivo software required local storage. To safeguard privacy the survey data was checked to ensure that no participants provided identifiable information, ensuring that no sensitive data is stored locally on the computer.

Data access during the study was additionally strictly limited to the researchers involved in the study. No information was given, sent or transferred to any other individuals during the study. Furthermore, no data was stored on USB devices in order to prevent the possibility of the loss of data. These measures were put in place in order to uphold ethical standards and protect the privacy of the individuals involved in the study.

Chapter 4 Limitations

In the following chapter the study aims to provide a comprehensive exploration of the limitations encountered during the study, this awareness of limitations is crucial in ensuring the accuracy and validity of the thesis and the studies undertaken during it. Through addressing these constraints, the study aims to uphold credibility in the field.

Firstly, the study is limited to a specific and narrow group of university students undertaking the Game Design course. While this approach offers in-depth insights into a particular subset of students, it imposes several restrictions. This restriction greatly reduces the sample size available in the study and may not account for many potential variations across different universities, student populations and curriculums. Therefore, it may not be appropriate to generalize the results to a broader spectrum of university students. Secondly, the select group of students may possess unique experiences compared to other Game Design students. They may have a deeper familiarity with technology and virtual environment compared to other Game Design students due to the study not accounting for prior Virtual Reality experience in participants. Moreover, the study's finding, conclusions and implications may not be readily applicable to students with different educational backgrounds when taking into consideration the possibly induced bias from the institution's unique culture, curriculum and resources with different universities having distinct teaching and learning environments which may influence students' responses to VR-based teaching methods. In summary, this limitation significantly narrows the scope and applicability of the study's findings, as they are primarily relevant to a specific subset of university students at one institution with only one experience of a Game Design curriculum.

Secondly, the focus of the study is placed exclusively on teaching locomotion techniques in VR. While this narrow focus provides an opportunity for in-depth exploration, it inherently limits the study's relevance when compared to other aspects of VR education, such as teaching students about programming for VR. In summary while the focused nature of teaching locomotion techniques in VR provides us with in depth insights it, however, limits knowledge on teaching other VR based topics in VR itself.

Another limitation encountered during the study is the possibility of the literature review being incomplete. The study's literature review may omit relevant studies and frameworks that could have positively contributed to the development of the teaching tool. These missing sources could have offered insights, alternative perspectives or methodological approaches that would have altered the development of the teaching tool and therefore alter the results in the study.

The accuracy and reliability of the teaching tool may be affected by this limitation making this a crucial limitation for the study.

The characteristics of the study participants, encompassing their levels of interest in Game Design and VR, as well as other individual differences including potential medical conditions represents a possible bias that must be considered when discussing the results of the study. The levels of interests in Game Design students towards VR is a vital factor in their responses and engagement in the study. Since the study exclusively focuses on Game Design students, it is reasonable to assume that these participants have a heightened interest in Game Design and VR, however, this may not apply to every Game Design participant and must be taken into consideration. Moreover, the presence of other individual differences, such as potential medical conditions, can introduce further complexity and bias in the study's results. These differences can cause a wide range of factors, including different learning styles required for different health conditions and health-related consequences that may make participants find it harder to experience the teaching tool. The study did not ask participants to disclose medical information nor did it ask participants to not attend the study with medical conditions, therefore a bias may be present in the results.

The data collection primarily relies on self-reported surveys, a common method in social sciences. However, this approach is susceptible to social desirability bias and inaccurate responses from participants. Participants may misunderstand questions and concepts during the survey which leads to incomplete and unreliable responses, potentially distorting the participants' true experiences and opinions. Additionally, participants may have different understandings of words and concepts based on their knowledge English and the areas they were raised in, with many words potentially holding other meanings for participants.

The use of the Meta Quest 2 may additionally pose limitational challenges, the technical capabilities of this platform, particularly concerning resolution, specifications, field of view and tracking accuracy may present constraints in the study. The low resolution of the Meta Quest 2 may lead to a pixalated and less visually immersive experience, which may have affected the participant's engagement and overall quality of the teaching tool. Moreover, the tracking accuracy is a crucial component when teaching locomotion techniques. If the tracking accuracy is not optimal due to a software update, bugs, or the system itself it may cause lag or misalignment between the participants' movements and the actions in the virtual environment. Some participants reported in the study experiencing bugs, glitches and snappy movement which may have contributed to the experience participants have experienced. Additionally, it is crucial to keep in mind that participants used different Meta Quest 2 units, which may have been updated differently, experienced different internet connection or have been differently calibrated therefore participants may have had different experiences affecting their learning outcomes.

In addition to the previously discussed limitations, the study confines to a single VR device posing an additional limitation. The study's reliance on a single VR device, in this case, the Meta Quest 2 restricts the amount of locomotion techniques that can be shown and used during the teaching tool. With different VR devices offering different locomotion techniques the research misses out on the opportunity to showcase other locomotion techniques in VR and the effectiveness of education of those locomotion techniques in VR.

The study additionally utilises Mozilla Hubs when executing the teaching tool. Mozilla Hubs is an online teaching tool with the ability to create accessible environments that can be used on the web or VR device. The application requires constant internet access and additionally is an open source application constantly developed by volunteers. This application comes with limitations which may have hindered the study and the results. Firstly the application requires constant internet access, this means that during times where the internet access was less strong or a connection broke participants will have experienced a slower experience or none at all compared to participants who had good internet access throughout the study. Secondly, the application also has many bugs and glitches due to it's constantly in development status, this means that participants may have encountered experience breaking glitches and bugs that hindered them from fully experiencing the teaching tool in the same way to participants who encountered no glitches or bugs. The limitations stated may have caused participants to provide responses that were affected by internet connectivity, bugs and glitches which may not reflect the learning outcomes participants would have experienced in a perfect environment.

Lastly, VR is known to potentially cause motion sickness in individuals. During the study some participants may have had symptoms of motion sickness, impairing their ability to experience the teaching tool in the intended manner. This may have causes bias when answering the survey and caused participants to experience different learning outcomes compared to participants who have not experienced motion sickness during the experience.

In conclusion, the study's constraints must be acknowledged as the methodological limitations. Recognizing and addressing these limitations is crucial as it emphasizes the need for further research in the field that extends beyond the constraints of the study. Additionally, recognising these limitations is fundamental for exploration of the VR-based education field and its potential applications in educational settings.

Chapter 5 Design Decisions

The following chapter will examine the design choices that have shaped the development of the immersive teaching tool, along with the motivations and reasoning behind these decisions. The chapter will delve into the utilization of the created framework, the technical considerations undertaken and the general evolution of the tool. Through this exploration the aim is to provide a understanding of the decision-making process behind the creation of the tool.

5.1 Technological Considerations

The following section within the design chapter outlines the technological considerations that were crucial during the development of the immersive teaching tool. The section specifically addresses the choices made during the evaluation of the available VR headsets to use in executing the teaching tool, the selection of software used in its creation and other essential factors such as ensuring accessibility to participants with potential disabilities.

5.1.1 Headset

During the development of the immersive teaching tool, a critical and crucial aspect of the process involved the evaluation of the various VR headsets available with a focus on their advantages and limitations. One of the main research objectives during the research was to create a financially accessible teaching tool for schools and universities.

Early in the exploratory phase, the Google Cardboard was the first choice for consideration due to its affordability and simplicity making it an attractive choice in line with the research objectives creating an accessible educational experience. However, during the testing phases of this tool it became clear that while Google Cardboard was affordable and accessible it unfortunately lacked in crucial aspects. One of the primary limitations encountered was the Google Cardboard's computational power. The immersive teaching tool required a VR device that allowed for tracking with controllers and enough computational power to run a fully 3D graphical experience.

Moreover, the absence of controller support was another critical drawback that was discovered in the Google Cardboard. Interactive components and control mechanisms were crucial when creating a VR teaching tool that focused around movement in VR itself. The inability of the Google Cardboard to accommodate controllers, tracking and most movement hindered the capacity to offer an immersive teaching tool within it.

While the Google Cardboard had initially appeared promising for the research due to its affordability, its limitations made it clear that alternative options needed to be considered.

The second VR headset evaluated during the research was the Google Daydream. While the Google Daydream had several advantages over the Google Compared, including the inclusion of a controller and a head strap it too was presented with many limitations that could not be overlooked during the study.

Similar to the Google Cardboard, the Google Daydream was constrained by its reliance on a mobile device for its processing power. This limitation meant that it could not efficiently run more resource-intensive experiences especially ones not utilized for mobile devices. Additionally the tracking capabilities of the Google Daydream were found to be a limitation, with the tracking similar to the Google Cardboard there was no way for participants to effectively carry out interactive tasks and move within the VR space in the Google Daydream.

As a result, while the Google Daydream represented an improvement over the Google Cardboard in terms of it’s controller support and comfort features while maintaining it’s accessible price point. Its shared limitations in terms of the computational power and tracking capabilities made it clear that more exploration was needed into alternative VR headset options.

The final VR headset under consideration was the Meta Quest 2, with its accessible price point for educational institutes the Meta Quest 2’s advantages and disadvantages were taken into consideration.

One of the significant advantages of the Meta Quest 2 was its support for two controllers, with both headset and controllers featuring tracking capabilities this was marked as a substantial improvement over the Google Daydream and Google Cardboard that had very little tracking capabilities available. However, it is worth noting that the Meta Quest 2 was relatively bulkier and less comfortable to wear, primarily due to its larger size compared to the previously considered headsets.

A secondary advantage of the Meta Quest 2 was its software compatibility, the Meta Quest 2 supported a wider range of applications with a greater compatibility support especially with Mozilla Hubs. This provided a smoother and less lag-prone experience in Mozilla Hubs. An additional advantage that the Meta Quest 2 shared with the Google Cardboard and Google Daydream was its accessibility to users who might have physical limitations, as it allowed individuals the ability to sit through the experience with the stationary boundary rather than requiring them to stand or walk throughout the duration of the experience.

After taking into considerations the advantages of each individual VR headset it was decided to incorporate the Meta Quest 2 into the study due to its numerous advantages combined with its affordability making it a suitable choice for the research.

5.2 Software

Several pieces of software were taken into consideration during the research, in the following chapter each software will be discussed with rationale for why this software was or was not employed into the research.

Throughout the immersive experience's development, an equally crucial aspect was the selection of the software to be used for distributing the educational tool. This software needed to align with the research objectives which centred on financial accessibility. Secondly the software needed to posses a wide array of tools to fully allow for the implementation of the newly created framework. The choice of software was a crucial aspect of the research and was pivotal in achieving the research objectives.

5.2.1 Spatial

Initially, Spatial was considered as a solution for ensuring accessibility and providing a diverse set of tools in order to create the immersive environment. Spatial which was developed by Spatial Systems (2023), offers users the capability to design their own environments using pre-developed tools before transferring them to a VR headset. The platform's free-to-use nature ensured accessibility which aligns with the research objective 'to construct a financially accessible teaching tool'. Upon testing, the platform demonstrated a good set of tools which would enable the creation of complex environments. However, Spatial appeared to have several drawbacks which would hinder the research significantly.

Upon the initial evaluation of Spatial, it became apparent that the software had certain drawbacks that posed challenges in the research with the chosen headset. Notably, Spatial exhibited a high demand for an intensive graphical environment, causing performance issues within the headset selected, Meta Quest 2. While a change in headsets was considered and was a potential solution in addressing this specific challenge and shifting to a more compatible headset would potentially resolve the performance issues, however, this would also compromise the accessibility factor of the research that was outlined in the research objectives.

Furthermore, during the testing of the software, there were additional concerns which emerged regarding the functionality of Spatial. This was seen particularly in its ability to handle a multiple-room environment. During testing in instances rooms within the Spatial environment became glitchy and in some cases, crashed, especially when experiencing fluctuations in the Wi-Fi connection. The potential for spatial glitches and crashes raised a significant concern about the reliability of the software during a story, posting a threat to the validity and consistency of the educational tool.

Following the experimentation conducted with the Spatial platform, the decision was made to seek an alternative platform that could offer both accessibility and reliability due to the identified issues such as performance challenges and unpredictable behaviour of the software.

5.2.2 Unreal Engine

Unreal Engine, developed by Epic Games in 1998, was considered as an option during the research, this software offered a wide array of tools that particularly offered the creation of complex VR environments. With full support for VR development and the capability to create experiences from the grounds up with full programming support Unreal Engine initially aligned with the research. Unreal engine additionally aligned well with the research objectives of constructing an accessible teaching tool. The free price model of Unreal Engine further emphasized the tool's appeal in in terms of the research objectives.

However, despite Unreal Engine's toolkit and capabilities seen during experimentation, several challenges arose. One significant drawback was Unreal Engine's limited compatibility with VR headsets, especially the Meta Quest 2. The difficulty arose in the inability to add software directly to the Meta Quest 2 posing challenges in effective usage of the teaching tool.

Moreover, Unreal Engine shown the need for high resource intensity, demanding a powerful system during the development of the tool. This raised concerns during the research in the area of financial accessibility, as the requirement for hardware may pose limitations in educational environments where these resources may not be readily available.

In addition, Unreal Engine's reliance on programming, modelling and game engine knowledge presented additional accessibility challenges. The need for this knowledge could potentially hinder the accessibility of developing educational software, especially for users with varying levels of technical proficiency.

Given these challenges, it became clear that while Unreal Engine had powerful tools, its compatibility issues with VR headsets, resource-intensive nature, and required technical proficiency posed considerable challenges when considering Unreal Engine in relation to the research objectives. The decision was undertaken to further explore other possible software solutions.

5.2.3 Mozilla Hubs

Mozilla Hubs, developed by Mozilla in 2018, was the final software considered for the study. This free-to-use platform allows users to create VR-compatible environments using the packaged software Spoke. Notably, Spoke enables users to develop environments entirely within the browser, providing support for free-to-use models and functionalities without the need for programming or technical proficiency. This point of accessibility aligned with the research objectives outlined.

During the testing of the software, Spoke featured a range of tools that facilitated multi-room creation, audio integration and inclusion of video content. Multi-room creation was especially important with the consideration of the framework's requirements for Segmented Tasks (Mulders et al. 2020). Furthermore, Spoke offered an accessible means to create VR ready environments without imposing costs on the users, aligning with the accessibility research objectives of the research.

One notable advantage of Mozilla Hubs was its low system requirement during testing, this provided greater accessibility with the enhanced usability across various technological environments. Secondly the transfer of the created tool onto the VR headset, Meta Quest 2, through Mozilla Hubs provide straightforward. Through opening the default internet browser on Meta Quest 2, a code could be entered which allowed to instant teleportation to a fully functional and full-screen VR experience. Furthermore, an important factor considered was the smooth experience that was unaffected by internet fluctuations ensuring a reliable experience.

However, it's essential to acknowledge that Mozilla Hubs does have its limitations, particularly in the areas of programming and the ability to important many models. This constraint slightly impacted the creation of the teaching tool as it was not possible to important a range of models or program specific experiences that could support the tool and create more rich experiences. Despite the limitations encountered in testing Mozilla Hubs was the most viable option among the software tested due to its accessibility, in terms of ease of use and price point as well as it's compatibility with Meta Quest 2. Additionally the software still offered numerous features and tools that allowed for the creation of a tool that followed the framework and allowed for the execution of locomotion techniques.

5.3 Locomotion Techniques

Multiple locomotion techniques were considered when planning the study. The study's focus was on using the framework in order to create an experience that used real teaching theory as the foundation, by doing this the study required the construction phase. The construction phase of the framework requires participants to go through some sort of learning activity to be able to build and solidify their knowledge from the conceptualisation stage. The hands-on experience was decided upon by analysing the Deriving Learning Activities which recommends applying knowledge as a part of the construction phase (Fowler, 2015).

To use locomotion techniques that aligned with this framework and in turn aligned with the research objectives, it was essential to utilise techniques that were supported by the Meta Quest 2 and Mozilla Hubs. Mozilla Hubs supported two locomotion techniques, the controller and point-and-click (also known as the teleportation) technique. These two techniques were chosen for the study due to their support by the software and hardware.

The experience additionally features one room which will present to participants other locomotion techniques not supported by the Meta Quest 2, this room will not use the framework as it's foundation and instead will be used to analyse the effectiveness of the framework by comparing the participants perspectives on their learning outcomes.

When analysing which locomotion techniques were to be chosen as part of the last room, a lot of reference was made back to the literature review which acted as a guide for the locomotion techniques that could be chosen. It was logical that chosen locomotion techniques must not be experimental and must be commercially available as the aim of the study is to teach game design students the effects of locomotion techniques on users, with experimental non commercialised locomotion techniques often the effects on a wider user base are unclear. The locomotion techniques chosen in the end were the Omni-directional treadmill, the top down perspective, automated locomotion, gesture based and room-scale based. The chosen locomotion techniques all had enough information in order to understand their effect on user experience.

5.4 Singular vs Multiple Rooms

When deciding the format of the study itself considerations were made in regard to the overall layout and structure of the experience. One of the crucial decisions was the number of rooms to be shown in the experience. Mozilla Hubs supports both singular and multiple rooms, allowing the experience to take both very different structures.

Singular rooms allowed for a more streamlined process, being contained in one experience on the device participants did not have to be concerned with teleporting to other areas. Additionally, concerns about loading times was not relevant as everything would be loaded on the start of the experience. However, single room experiences suffered in other areas. With a singular room experience it was difficult to import all necessary assets without drastically impacting the performance of the experience, secondly importing multiple video and audio aid into a singular room caused technical difficulties. Lastly a singular room experience did not promote segmented tasks and guided learning, allowing participants to not be overwhelmed by the amount of information provided to them.

Multiple rooms allowed for a more technologically sound experience, with assets and files being separated into rooms the experience loaded faster and suffered less lag. It was crucial for technological lag to not impact the participants perception of the environment as this could potentially cause inaccurate results. Secondly multiple rooms allowed for a better implementation of the created framework, by utilising multiple rooms the experience fit the segmented tasks and guided learning aspects of the framework through ensuring that tasks are separated, and that learning is guided in a linear fashion.

In conclusion, both the singular and multiple room approach offered different benefits and drawbacks, however, with the aim of the study focusing on the correct implementation of the correct framework it was logical to take the multiple room approach allowing for the study to be guided and segmented as according to the framework.

5.5 Summary

In conclusion the chapter discussed and provided rationale for the decisions made during the creation of the environment. The chapter provided information on the technological approaches including the choice of headset and software with analysis provided for the reasoning behind each decision. Additionally, experimentation was done in order to make design decisions. Secondly information was provided of design decisions undertaken in the actual creation of the software in relation to the locomotion techniques chosen and the structure chosen for the overall experience with rationale linking back to the framework and learning objectives. In conclusion the chapter draws onto the framework and core research objectives when deciding upon crucial design decisions.

Chapter 6 Environment Execution

The following chapter focuses on the practical execution and creation of the immersive environment. In contrast to the previous chapter, 'Design Decisions' which delves into the decision-making process for the study. This chapter aims to provide detailed information on the process of creating the environment itself rather than reasoning behind specific decisions such as the use of Mozilla Hubs. The primary purpose of this chapter is to offer insight into the challenges and solutions faced during the study, in order to create a guide to provide future work the ability to recreate this environment. Lastly this chapter aims to provide clarity on the methodologies employed and the reproducibility of the research.

6.1 Overview of the environment

The immersive environment was partitioned into four distinct rooms. Each room was dedicated to showcasing a specific locomotion technique alongside an activity connected to the locomotion technique in that room. The introduction and gallery rooms were exceptions and were not centred on a singular locomotion technique. The purposeful segmentation aligned with the Segmented Tasks (Mulders et al. 2020) aspect of the framework created in the Methodology chapter. Firstly, this potentially prevented participants from feeling overwhelmed during the experience and secondly, the decision to use four rooms allowed for better technical performance by distributing the load across multiple rooms.

The decision was made to only utilize models found in Mozilla Hubs Spoke, this choice allowed for a more streamlined creation of the experience but also alleviated concerns of copyrighted content that could negatively impact the research's usability. The entirety of the development process was conducted within a web browser on a computer, using the capabilities of the Mozilla Hubs Spoke software with all testing underdone within the Meta Quest 2. This browser approach was selected due to it's accessibility but also flexibility. The testing underdone in the Meta Quest 2 ensured that the environment was adequate for the VR space and that the user experience was accurate to what was being developed.

The primary focus throughout the development process was centred on creating an immersive experience environment that was supported by established frameworks as well as prioritised accessibility.

By incorporating recognised frameworks, the developmental approach was supported by pedagogical foundations, aligning the immersive experience with established educational theories. This added depth to the experience was the core research objective throughout Masters degree.

One of the research objectives states the following ‘Apply the developed framework from the literature review to construct an accessible teaching tool in Mozilla Hubs educating students on locomotion techniques and their impact on user experience ‘, this research objective is crucial during the development of the tool. When discussing accessibility it is crucial to understand that in the context of this research accessibility refers to both financial and developmental accessibility. Both allowing the experience to be affordable for educational institutions but also easy to create and implement in education. While consideration during the study was undertaken into accessibility for users with disabilities in order to ensure that the study is ethical and as inclusive as possible, the study’s main focus is not on medical accessibility.

In order to fulfil the goals of this research objective the accessibility described was one of the main goals during the development of the tool. From the platform choices to the headset, the choices undertaken during the study ensured that the experience was accessible to educational institutes. The use of Mozilla Hubs was deliberate due to the application’s accessibility, with Mozilla Hub’s free to use model and it’s accessible nature it was the natural choice as discussed previously in the Design Decisions chapter.

Throughout the creation of the environment one of the other crucial research objectives had to be considered ‘Develop an accessible, easy-to-use framework supported by current frameworks identified in the literature review to be used in higher education when teaching locomotion techniques and their impact on user experience in Virtual Reality itself’ this objective influenced the environment’s creation through the need to align the framework with the environment itself.

Throughout the creation of the environment the framework served as a standard guiding the environment itself, ensuring that every decision made was connected and contributed to the research objective. This means that every room in the experience was supported by the framework itself, ensuring that the rooms and activities used real teaching theory. The goal was to establish an environment that was primarily guided by pedagogical approaches steering away from the creation of an environment that lacked solid teaching theory to support it. The integration of the framework was crucial in this process, which allowed us to fulfil the research objective and create an environment that was supported by real teaching theory.

6.2 Introduction Room

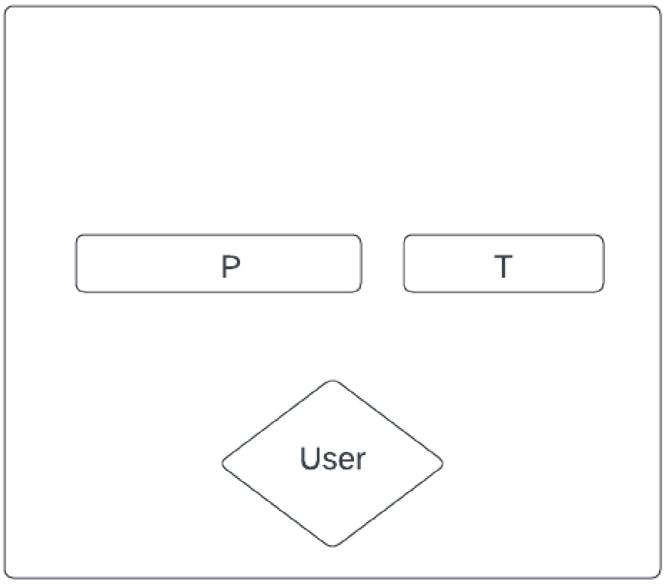

Figure 17 Diagram showcasing the introduction room

The following section describes the first room that can be found in the immersive experience, this section aims to describe the room, its purpose and the usage of the framework within it.

The visual depiction above (Figure 17) provides a visual depiction of the introduction room. This room, referred to as the introduction room, marks the start of the experience. This room is the first room that participants experience when first delving into the immersive experience.

The room features an audio voice over, the audio voice over is designed to provide users with detailed introduction to the overall immersive experience, allowing participants to understand and receive information that is relevant to the overall experience. The audio features guidance on the controls in the experience as well as safety warnings addressing the possibility of motion sickness. This is crucial in the experience ensuring that participants are aware of the possible safety concerns when using VR.

In this room, denoted by the ‘P’ is a screen that is positioned to the left of the user, serving as an important aspect of the introduction room. This screen provides a brief yet informative demonstration of the controls crucial to using the Meta Quest 2 effectively. This component of the room aligns with the created framework’s conceptualization stage, in which participants receive information establishing a foundational understanding of the movement in the immersive experience.

Following the video shown on the screen, participants are encouraged to experiment with the controls within the room. This phase additionally aligns with the construction stage of the framework. Within this stage participants are encouraged to apply and experiment with the knowledge that they have acquired during the conceptualization stage. This hands-on experience of the controls serves to solidify the participants' understanding and proficiency of the knowledge they have just learned.

In conclusion, the incorporation of the screen and audio content ensures interactive engagement and connection to the created framework. It reflects the conceptualisation, where information is conveyed, and the construction, where participants actively apply their newly acquired knowledge.

The last feature of the room is the teleportation button, designated as 'T' on the diagram, which is a notable feature of the immersive experience. This functionality grants participants the option to transition to the next room independently. This was an intentional choice in order to align with the self-guided segment of the framework, ensuring that participants can experience the environment at their own pace.

Moreover, the teleportation feature contributes to the implementation of the segmented learning approach within the framework used. The presence of multiple rooms provides a structured and segmented learning experience where participants can navigate through different segments rather than using one room.

In summary, the introduction room incorporates essential elements that are crucial for the execution of the framework. The introduction room utilizes the framework and maintains core principles of the framework. This initial space plays an important role in the user guidance, providing clear instructions that enable users to understand how to navigate the immersive experience effectively.

6.3 Point-And-Click Room

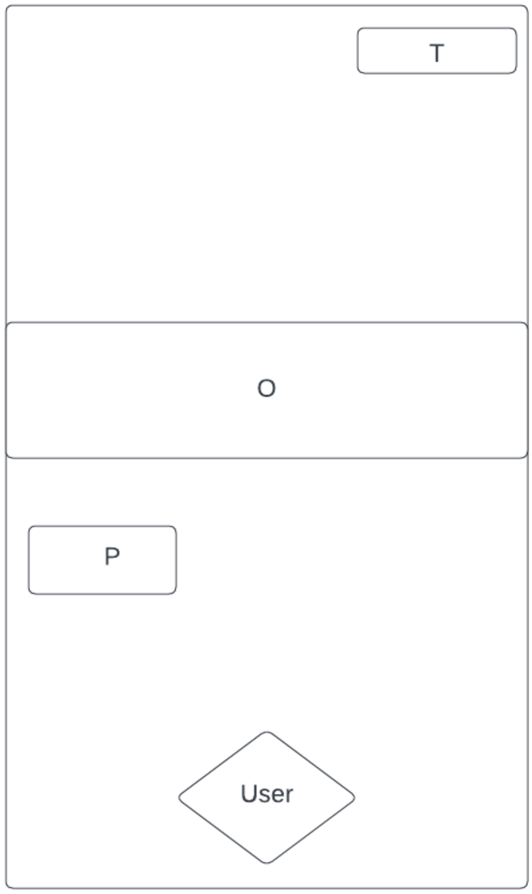

Figure 18 Diagram showcasing the Point-And-Click room

The Point-And-Click room represents the first room that focuses on teaching a locomotion technique known as the 'Teleportation' or 'Point-And-Click' technique. Participants are tasked with applying this technique to overcome an obstacle denoted by the symbol 'O' (Figure x). This approach serves as a means for the participant to engage in a problem-solving activity which is directly influenced by the construction phase of the overarching framework.

The choice of an obstacle in this room is deliberate, this directly uses the advantages of the Point-And-Click technique. Participants through employing this method gain an understanding of the advantages of the technique with the ability to teleport around the room and effectively move over obstacles, something that is not possible with the controller technique that participants learn about in this experience. As the research objective aims to educate participants on the effects of locomotion techniques on user experience, it makes sense to educate participants about how the locomotion technique can be utilized in the virtual space.

Within the Point-And-Click room, a screen denoted as ‘P’ (Figure x) plays a video alongside a voice over, this guides the participants on the navigation process of the Point-And-Click technique. As the introduction room only features basic controls it is likely that participants do not fully understand how to use the Point-And-Click technique yet, making a video and audio voice over crucial. The usage of a video that provides information with the audio voice over additionally aligns with the conceptualisation stage of the framework. The voice-over additionally features information on the benefits and negatives of the Point-And-Click technique, this touches on topics discussed in the literature review such as immersion, motion sickness, ease of use and other effects locomotion techniques may have on user experience. This is crucial in allowing participants to actually understand the effects of the specific locomotion techniques on the experience of users.

Following the audio voice-over guidance participants engage with the Point-And-Click technique hands-on by attempting to navigate the experience using this technique and overcome the obstacle. This hands-on experience not only serves as a practical hands-on experience of the locomotion technique but also aligns with the construction phase of the framework. Participants through their direct involvement have the opportunity to build on their knowledge, another segment of the framework, gaining a deeper understanding of the effects and implications of the locomotion technique in a practical context.

By personally navigating the environment and having the opportunity to use the locomotion technique hands-on participants additionally gain insights into the nuances of the locomotion techniques especially their impacts on user experience. For example, participants may understand why one locomotion lacks immersion compared to another by directly experiencing these effects.

Additionally, visual aids such as images, questions, and discussions prompts are placed on the rooms’ walls, allowing for participants to engage in reflection, this aligns with the dialogue stage and the building on knowledge stage of the framework. Firstly allowing participants to engage in dialogue and reflection on content they have been taught and secondly build on the knowledge they have been provided with additional questions and activities that deepen their understanding.

In conclusion, the Point-And-Click room provides participants with information and hands on experience of the Point-And-Click locomotion technique. The use of the multimedia approach, including video and audio content, uses the conceptualisation stage of the framework. Subsequent hands-on experience with the provided activity reinforces the construction phase allowing participants to actively build on their knowledge and understand the impacts that locomotion techniques may have on user experience. The inclusion of visual aids on the rooms' walls which encourages engagement and reflection, aligns with the dialogue and building on knowledge stages of the framework allowing participants to reflect on the knowledge they have learned in the room.

6.4 Controller Room

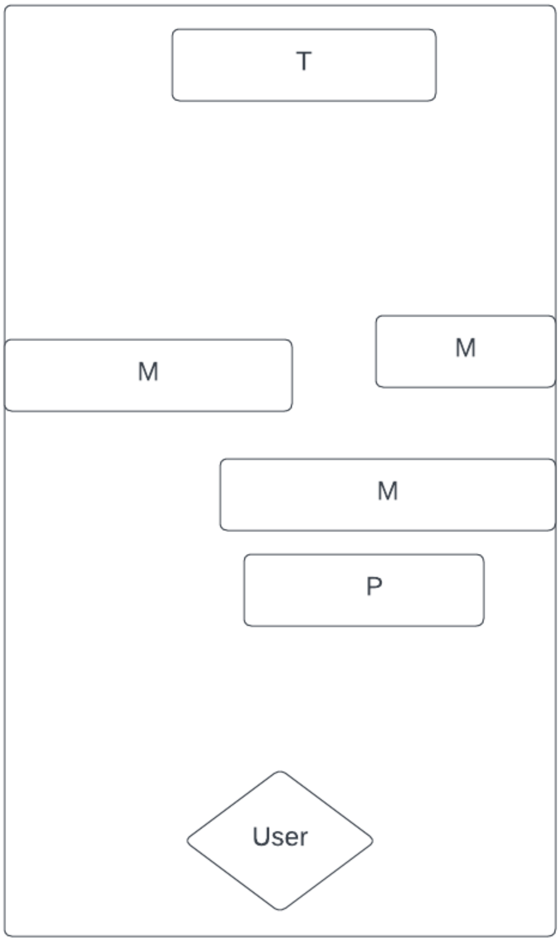

Figure 19 Diagram of controller room

In this segment of the experience, the objective is to enable participants to immerse themselves more deeply in the understanding of locomotion techniques and their effects on user experience, specifically through the controller technique itself. While a single room dedicated to one locomotion technique could be an option for the study, it might not provide the comprehensive insight into the potential effects of the framework on participants. Additionally, a singular focus wouldn't capture insights of how participants perceive the process of learning VR by actively engaging with VR itself.

Similar to the Point-And-Click room, this section functions as a dedicated space for participants to further delve into specific locomotion techniques and their influence on user experience.

Upon entering this section, participants encounter an informative audio voice-over presented as P on the diagram above. This guide provides step-by-step instructions on navigating the virtual environment using the controller technique. Beyond navigation, the voice-over serves as an introduction to the technique, discussing both its advantages and drawbacks, highlighting its direct impact on the overall user experience. Participants have full control over the audio, allowing them to pause, start, and rewind the voice file as needed. This directly links back to the self-guided component of the created framework allowing participants to have an agency on their learning. The audio-voice over additionally acts as the conceptualisation stage of the framework, allowing participants to receive new information. Additionally to assist participants further with the conceptualisation stage a video is played in the room allowing participants to watch the controller technique in use, the video can again be paused and played supporting self-guided learning, this segment of the room further solidifies the conceptualisation stage.

After participants experience the audio voice-over and the video available in the room, they are tasked with a small activity. Participants are asked to overcome a maze (Marked as M) in front of them which requires them to use the controller method. The reasoning behind this is attributed to the locomotion techniques themselves and the differences between them, the Point-And-Click technique allows you to jump over obstacles in the VR space, something the controller technique is unable to do. On the other hand, the Controller technique allows participants to navigate mazes and small spaces where the Point-And-Click technique usually struggles to register movements causing confusion in users. Therefore, a maze was incorporated into the experience allowing participants to experience hands-on the different usage scenarios that locomotion techniques can support. Throughout the experience the audio voice-over additionally informed participants of this encouraging them to experience with both locomotion techniques to understand the difference between the locomotion techniques. Another crucial aspect of the activity is it's link to the framework created for the study, by allowing participants to undergo this activity the framework's construction stage was incorporated. The construction stage is where participants are given the opportunity to use the knowledge they have gained through the voice-over and video (known as the conceptualisation stage) to further build on their knowledge, another stage of the framework, through construction.

The room further is supported by the segmented tasks component of the framework through the use of multiple rooms allowing for learning to be segmented into tasks. Throughout the room visual aid was placed allowing participants to participate in the discussion segment of the framework, the visual aid provided participants with questions where they could undertake reflection on their knowledge that they have gained in the experience.

At the end of the experience participants were asked to press the teleportation button (Denoted as T) in order to be transported to the next and last room of the experience.

In summary, the Controller room allows participants to directly engage with a fundamental locomotion technique. Through a straightforward and practical approach, it offers insights into both the advantages and drawbacks of the controller technique. This hands-on learning is facilitated by a structured teaching framework designed specifically for this study.

6.5 Gallery Room

Figure 20 Image of gallery in Mozilla Hubs

The gallery room is the last segment of the experience, the gallery room is a crucial part of the overall experience allowing participants to learn locomotion techniques through a different manner. The focus of this room is to teach locomotion techniques without the use of the teaching framework, this was crucial in gaining insights into how the teaching framework affected the experience. For example, seeing participants responses to areas that used the teaching framework and responses to rooms that were not using the teaching framework allowed for a deeper understanding of the effectiveness of the framework itself.

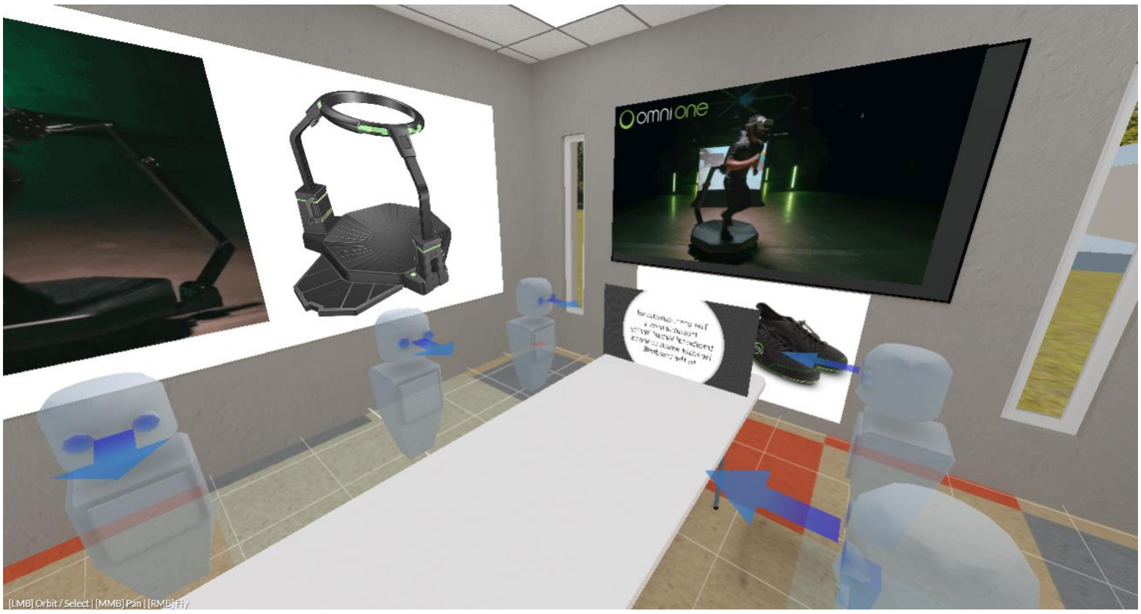

Figure 21 Image of room in the Gallery Room presenting the omni-directional treadmill room

The room features 5 breakout rooms, each breakout room focuses on a singular locomotion technique, all locomotion techniques that were chosen are not supported by the Meta Quest 2. As the Meta Quest 2 supports only two locomotion techniques in Mozilla Hubs, these were used for the hands-on activities that were essential in the construction phase of the framework.

Each room featured visual and audio aid, the visual aid comprised of videos which showcased the different locomotion techniques focused on in that room. The accompanying audio aid supported this by discussing the various positives and negatives of each locomotion technique, while this section of the room can be taken as the 'conceptualization' phase it is crucial to understand that the teaching framework only works if each stage is employed, and in most experiences the conceptualization stage can be found as to achieve it the experience must simply provide information to the user.

Past the conceptualization stage there were no other frameworks used, no activities were provided, no discussion was encouraged and none of the concepts of the frameworks were implemented. This allowed for participants to experience a very different style of teaching, one that did not provide a hands-on experience but still allowed for the learning of VR to happen within VR itself.

Participants were informed that when they wish to exit the experience to simply take off the headset, as the gallery was the last room in the experience there was no other segments for participants to take part in. It was crucial for the gallery to be the last room in the experience, if the gallery took place in the middle of the Point-And-Click and Controller room it would break the framework's Segmented Tasks segment by including a room that was not connected to the framework in any manner.

After participants completed the experience, they were invited to participate in the short survey on Jisc, this survey took around 5-10 minutes of participants' time.

6.6 Summary

In conclusion the chapter addresses and discusses the execution of the environment itself with provided figures showcasing the environments plan and creation. The chapter additionally discusses the frameworks incorporation into the experience with the core research objectives in mind. Secondly, the rationale behind decisions that were executed during the creation of the environment are discussed with links back to the framework and the research objectives. Lastly the chapter outlines the experience that participants took part in allowing for future work to recreate the study effectively.

Chapter 7 Results

The following chapter aims to report the results of the study in a non-speculative manner, additionally providing the themes and codes used in the data analysis of the study. The aim of the research is to evaluate the effectiveness of the teaching framework created through the use of qualitative surveys in order to assess, understand and review the effects of the developed teaching tool on students. Additionally, the aim of the paper is to compare traditional VR teaching methods with the use of VR itself for VR.

Research Question	Themes that address the question
What impact does teaching University Students Virtual Reality locomotion techniques in the system have compared to traditional teaching methods on Game Design students?	▪ Preference for VR and Framework ▪ Negative Sentiments
What effects does teaching Virtual Reality locomotion techniques with a framework in the system have on students specializing in game design at the university level?	▪ Positive Attitude Towards Framework and Experience ▪ Preference for VR and Framework ▪ Negative Sentiments
What effects does teaching University Students Virtual Reality locomotion techniques with a framework in the system have on Game Design students, in contrast to teaching the same techniques in the system without a framework?	▪ Negative Sentiments ▪ Preference for VR and Framework

Table 1 Table showcasing the themes and their relation to the research questions

Twelve participants were asked to fill out a short semi-structured survey. The data was thematically analysed in the Nvivo software and themes were created based on the research objectives. The Nvivo software allowed for the data to be coded and then sorted into themes to be used in addressing the research question and objectives. The software additionally allowed for the use for word clouds in order to strengthen the results from the study.

The study additionally employed structured Likert Scale questions, participants were asked to choose how much they agree with statements from a scale of Strongly Disagree to Strongly Agree. Results found in the Likert Scale will additionally be discussed in this chapter.

7.1 Positive Attitude Towards Framework and Experience

Initial Code	***Number of participants contributing***	***Number of transcript excerpts assigned***	***Simple quote***
Enjoyment of Hands-On Experience (Construction)	11	33	*'Being educated on the virtual environment and its traversal methods WITHIN virtual reality helped me get a grasp on the actual effectiveness of each traversal method by letting me have hands-on experience.'*
Enjoyment of self-paced component (Guided Learning)	3	3	*'I enjoyed the audio that changed direction as you changed your head and being able to pause the audio in case you need a break so you don't have to sit through it again if you miss a part.'*
Feeling of solidifying learning	2	2	*'It made the learning feel more cemented having my own experience of it.'*
positivity towards the use of multiple rooms	2	2	*'I believe that using multiple rooms tailor made to the specific forms of locomotion allowed for a more unique learning experience, and allowed me to interact with the environment and teaching apparatus in a way that a normal teaching situation could not provide.'.*
Positive Attitude Towards The Experience	11	38	*'i really enjoyed it! it allowed me to try out new forms of movement as i am learning about them making me a lot more engaged then if i was just watching a video.'.*

Table 2 Table showcasing the codes in the theme

Figure 22 Word cloud for 'enjoyment of hands-on experience'

Participants reported an overall positive attitude towards the framework. When asked about their opinion on the immersive experience participants typically reported an enjoyment of the hands-on experience with 33 references from 11 participants describing the hands-on experience, an aspect of the framework, in a positive manner, with one participant stating '' *Being educated on the virtual environment and its traversal methods WITHIN virtual reality helped me get a grasp on the actual effectiveness of each traversal method by letting me have hands-on experience.''* With another participant stating *'Getting hands on experience is unparalleled.'* One participant additionally felt that practical examples make most sense in learning VR *'It makes the most sense to learn in practice'.*

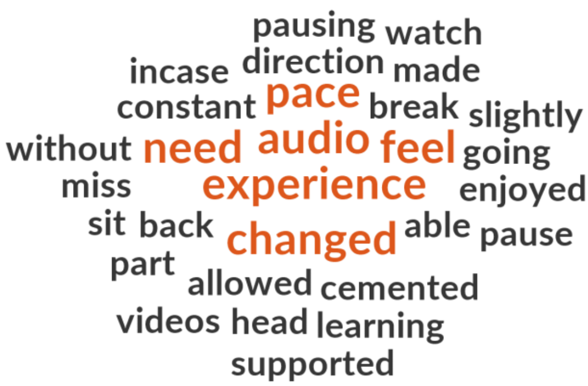

Figure 23 Enjoyment of self-paced component (Guided Learning)

Participants additionally positively described the self-paced aspect of the experience, which links to the guided learning segment of the framework. While participants were not inquired about their specific opinion on the self-paced aspect, 3 participants were found that spoke positively of the self-paced aspect from different participants when asked their opinion on the overall experience. One participant mentioned *'I enjoyed the audio that changed direction as you changed your head and being able to pause the audio in case you need a break so you don't have to sit through it again if you miss a part.'* With another participant specifying *''It allowed me to experience it at my own pace''*. There were no negative comments from participants regarding the self-paced aspect of the experience.

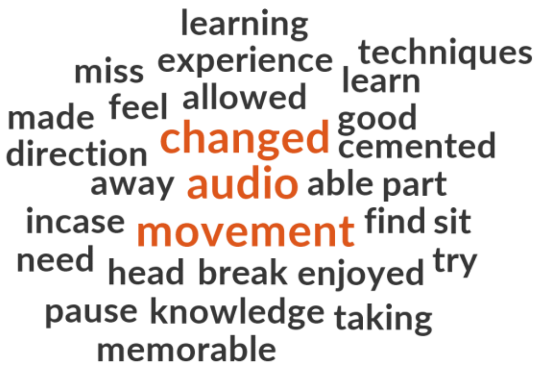

Figure 24 word cloud for Feeling of solidifying learning

Additionally, when participants were asked on their opinion of the experience as a whole, 2 participants stated the feeling of having solidified knowledge from the experience, another aspect of the framework. One participant stated *'It made the learning feel more cemented having my own experience of it.'* With another participant stating, *'i find myself taking away good knowledge on movement techniques.'.*

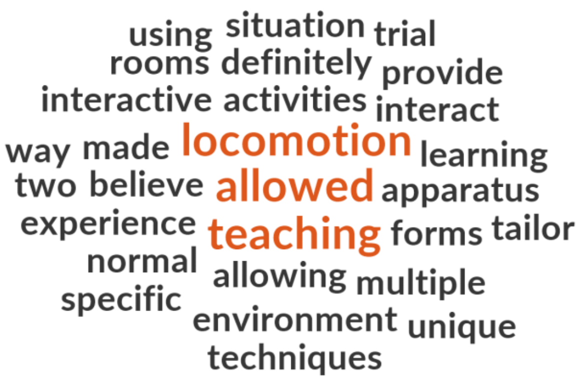

Figure 25 word cloud for positivity towards the use of multiple rooms

Participants additionally shown positivity towards the use of multiple rooms, the segmented learning aspect of the framework, without being prompted to discuss this aspect saying *'I believe* *that using multiple rooms tailor made to the specific forms of locomotion allowed for a more unique learning experience, and allowed me to interact with the environment and teaching apparatus in a way that a normal teaching situation could not provide.'*.

Figure 26 Positive Attitude Towards The Experience

Overall participants have shown a positive attitude towards the experience with 37 references coded from 11 participants. One participant described the experience as fun and engaging *'For me I find normal classroom experiences difficult due to ADHD and so the room based learning was hard for me due to attention span, whereas the practical examples were very fun and engaging!'* with another participant stating *'i really enjoyed it! it allowed me to try out new forms of movement as i am learning about them making me a lot more engaged then if i was just watching a video.'*.

7.2 Preference for VR and Framework

To understand the participants' preferences in the study, participants were asked for their preferences in relationship to the framework-based rooms versus the none framework based rooms using the created framework in the study. Participants were additionally asked their preferences for VR in comparison to traditional classroom settings.

Initial Code	***Number of participants contributing***	***Number of transcript excerpts assigned***	***Simple quote***
preference for the rooms utilising the framework	10	18	*'While the rooms with audio and video were good, I believe the interactive rooms were better for learning. It will allow any user to see how it actually works when they apply themselves into the VR space.'*
preference for VR over traditional classroom settings	11	18	*'it would definitely be more engaging with things being shown directs instead of in a screen on your pc'*

Table 3 Table showcasing the codes within the Preference for VR and Framework theme.

Figure 27 Word cloud for code 'preference for framework-based rooms'

Participants were asked their preference in terms of the interactive framework-based rooms compared with the none framework based room. Participants shown a preference for the rooms utilising the framework with 18 references created from the transcript from 10 participants. One participant stated *'While the rooms with audio and video were good, I believe the interactive rooms were better for learning. It will allow any user to see how it actually works when they apply themselves into the VR space.'* One participant additionally stated that the framework-based rooms kept them interested for longer which increased their learning outcomes *'The two interactive activities kept me interested for longer which helped me understand more.'* Another participant additionally stated that they have lost interest quicker with the non framework-based rooms *'I lost interest alot faster with the blank rooms with videos,'* Participants also positively described the ability for more experimentation offered by the framework-based rooms *'they allowed for more experimentation and showed the utility of each method.'.*

Figure 28 Word cloud showcasing preference for VR over traditional classroom settings

Participants additionally showed a preference for VR over traditional classroom settings, with 18 references extracted from the transcripts of 11 participants. Results have shown that 11 out of 12 participants preferred VR over traditional classroom settings when discussing the use of teaching Virtual Reality techniques. One participant stated that learning VR through VR is more engaging compared to using a PC to learn the same subject matter *'it would definitely be more engaging with things being shown directs instead of in a screen on your pc'* with another participant further commenting on preferring VR over consuming a standard video in a traditional classroom setting *'yeah, being able to learn them in real time was way better than say watching a video'.* Participants also expressed positivity towards learning locomotion techniques effects on user experience in VR compared to traditional classroom settings *'Definitely. It is one thing to be told that using a controller method to move around may feel* *awkward and possibly cause motion sickness, but entirely another to actually experience the movement methods hands on.'.*

Another participant also felt that the Virtual reality environment allowed for more varied teaching locations with the advantage of being able to undertake activities in the space *'The virtual reality allowed for more varied teaching locations, as well as provide activities within a space.'*

7.3 Negative Sentiments

To understand perceptions of participants on the experience negative sentiments were also recorded. This helped us analyse if participants felt more positive sentiments compared to negative sentiments about the experience. This was crucial in understanding drawbacks with the usage of VR to teach VR and understand how these may have affected participants' educational outcomes.

Initial Code	***Number of participants contributing***	***Number of transcript excerpts assigned***	***Simple quote***
Bugs & Glitches	9	16	*'sometimes I felt that minor bugs distracted from the immersion of the learning. Some scaling issues were also distracting as I felt the last few learning rooms were too tight.'*
lack of prior VR experience	2	2	*'I was a bit distracting since I'm one of many people who are new to vr, so it was distracting'*

negativity towards the experience	4	5	*'Again I think it needs refining, as I had trouble due to not knowing which buttons I was pressing, where I was going and such.'*
motion sickness	4	4	*'When I moved the position with the joystick I did start to feel slightly nauseous. This feeling subsided once I had stopped for a couple of seconds',*

Table 4 Table showcasing the codes within the Negative Sentiments theme

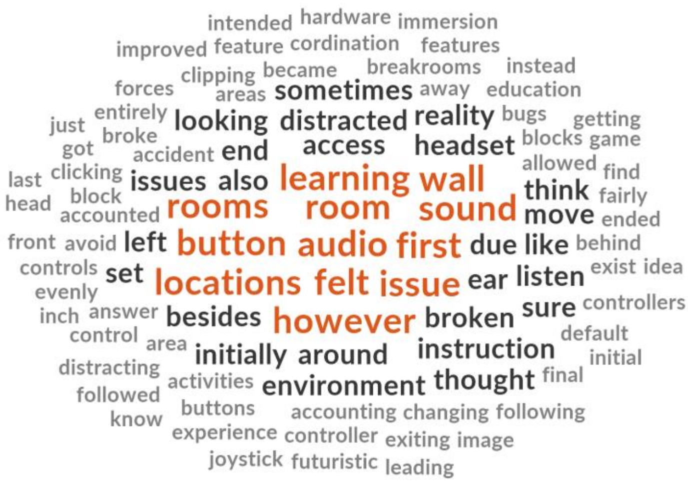

Figure 29 Word cloud for code 'Bugs & Glitches'

9 participants reported experiencing some form of Bugs & Glitches with 16 references extracted from transcripts. Participants tended to feel distracted from the immersion of the experience due to bugs and glitches they have encountered *'sometimes I felt that minor bugs distracted from the immersion of the learning. Some scaling issues were also distracting as I felt the last few learning rooms were too tight'*. Some participants encountered issues with the audio in the experience, with some reporting varying levels of volume levels in speakers *'Some of the audio tracks were clipping into objects in the level. This wasn't an issue for me as I didn't need to rewind them and had access to the play button. I'm also uncertain if this was an issue unique to my headset or something to do with the hardware and speaker placement but the audio seemed to be stronger in the left ear'*. With another participant also reporting issues in audio volume *'the audio got a lot quieter if you move a inch away from the spawn location'*.

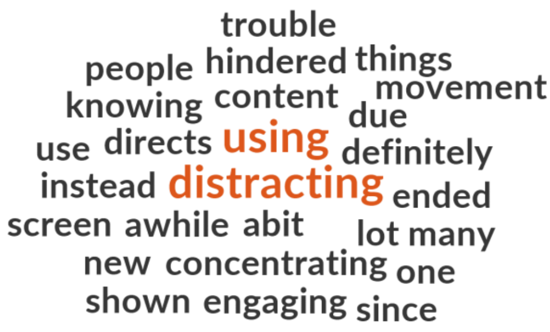

Figure 30 Word cloud for hindered by lack of prior VR experience code

2 participants reported feeling hindered by lack of prior VR experience, with 2 references found in the transcripts. One participant reported feeling distracted due to little knowledge on the usage of VR 'I was a bit distracting since I'm one of many people who are new to vr, so it was distracting' however, the same participant felt that with more experience in the VR system they would find it more engaging than using a screen on a PC 'after using it for awhile it would definitely be more engaging with things being shown directs instead of in a screen on your pc. Another participant felt hindered by their inexperience with VR, the participant felt like they had to concentrate more on movements and grasping VR over the content itself presented.

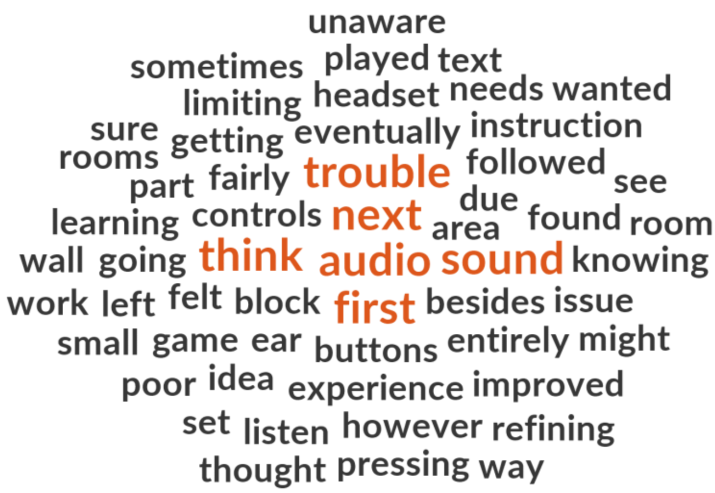

Figure 31 Negativity towards the experience code word cloud

4 participants expressed negativity towards the experience, with 5 references found in the transcript. Some participants felt that the experience required better instruction and refining, with participants struggling to navigate the experience and feeling lost on the controls *'Again I think it needs refining, as I had trouble due to not knowing which buttons I was pressing, where I was going and such.'* With another participant additionally adding that they felt unaware of what to do *next 'I was sometimes unaware of what to do next but eventually I found my way to the next part of the experience'*. No participants expressed negativity towards VR itself or shown

preference towards traditional classroom settings, participants negativity was expressed mostly towards navigation problems and finding the experience confusing.

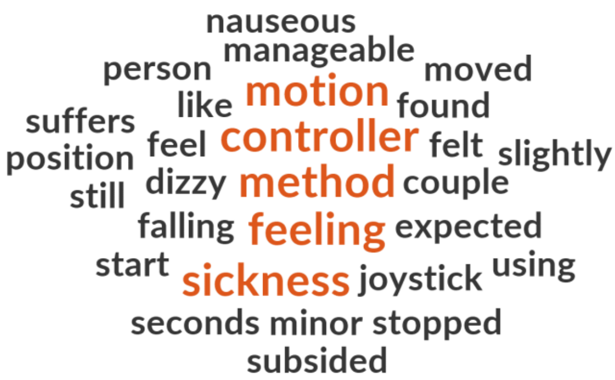

Figure 32 Motion Sickness code word cloud

4 participants reported feeling some type of motion sickness when using the experience with 4 references found in the transcripts expressing the feeling of motion sickness. One participant stated feeling motion sickness when using the controller method, something which is common for this method itself *'I felt some minor motion sickness when using the controller method, to be expected with this method.'* With another participant feeling similarly about using the controller method *'When I moved the position with the joystick I did start to feel slightly nauseous. This feeling subsided once I had stopped for a couple of seconds'*, most participants found the controller technique to cause motion sickness during the experience.

7.4 Likert Scale Questions

The survey included several Likert Scale questions which naturally were excluded from the qualitative analysis. The results of the Likert Scale questions will be addressed in this section. Participants were asked to answer the Likert scale questions based on the framework-based rooms rather than the last non-framework-based room, therefore the answers found in this section can only be related to the framework-based rooms.

7.4.1 I have found the experience to be disorganised or unstructured

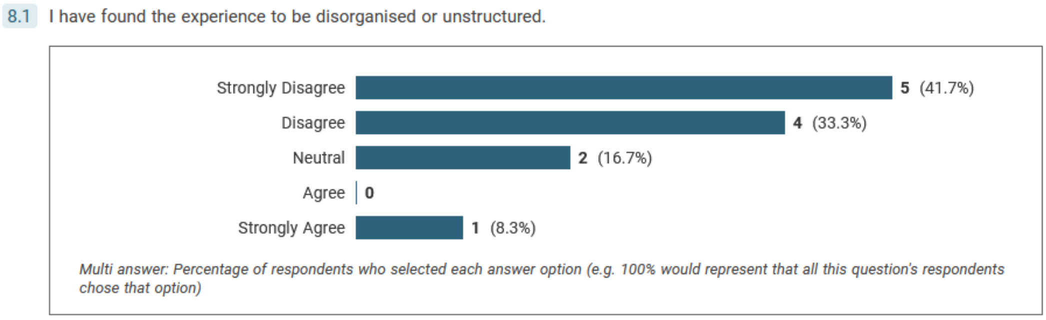

Figure 33 I have found the experience to be disorganised or unstructured survey result

Participants were asked if they agreed with the statement 'I have found the experience to be disorganised or unstructured' (Figure 33) 41.7% participants strongly disagreed with the statement, with 33.3% disagreeing. Additionally, 16.7% of participants were neutral to the statement and 8.3% agreed with the experience being disorganised or unstructured.

7.4.2 I have found the experience confusing to navigate

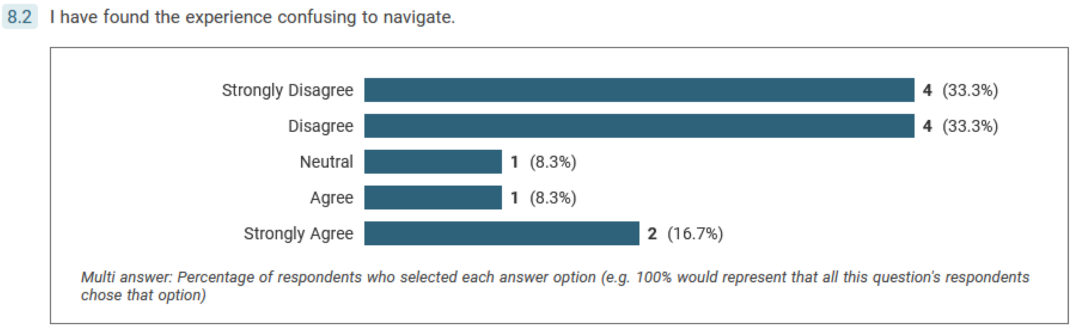

Figure 34 I have found the experience confusing to navigate survey result

33.3% of participants strongly disagreed with the statement 'I have found the experience confusing to navigate' (Figure 34) with an additional 33.3% of participants disagreeing with the statement. 8.3% of participants were neutral to the statement and another 8.3% agreed. Lastly 16.7% strongly agreed with the statement and felt that the experience was confusing to navigate.

7.4.3 I have found the activities useful and helpful in understanding locomotion techniques

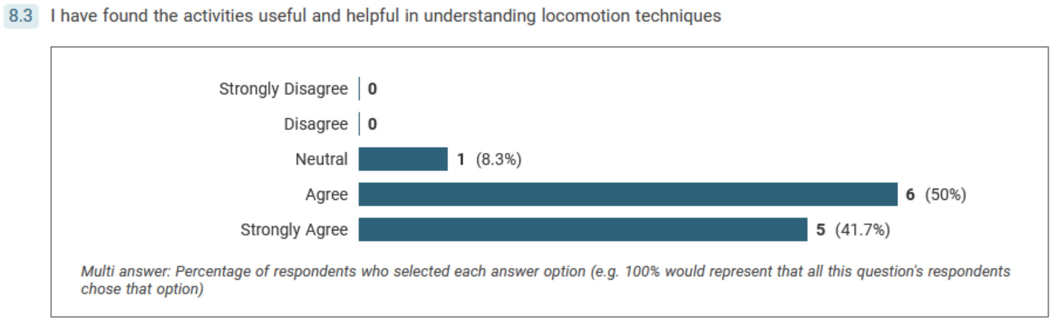

Figure 35 I have found the activites useful and helpful in understanding locomotion techniques survey result

When participants were asked 'I have found the activities useful and helpful in understanding locomotion techniques' (Figure 35) 41.7% of participants strongly agreed with this statement. 50% of participants agreed with the statement with 8.3% of participants feeling neutral to the statement. No participants felt that the activities were not useful or helpful in understanding locomotion techniques.

7.4.4 I didn't find the 'learn by doing' approach helpful in learning locomotion techniques

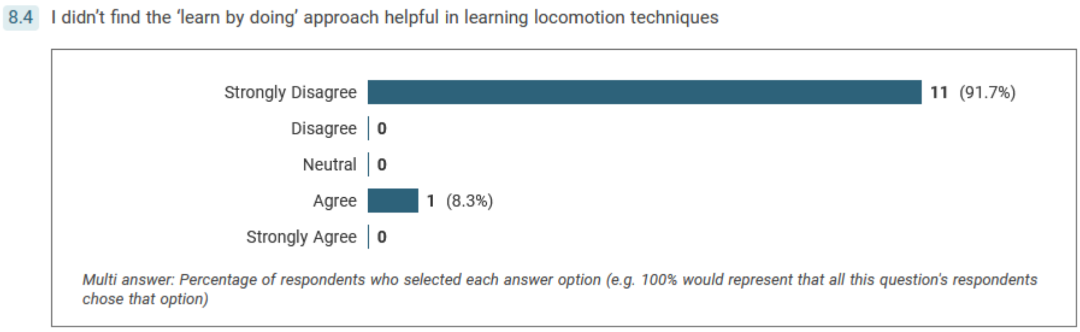

Figure 36 I didn't find the learn by doing approach helpful in learning locomotion techniques survey result

The last statement participants were asked to agree or disagree with was 'I didn't find the 'learn by doing' approach helpful in learning locomotion techniques' (Figure 36). 91.7% of participants strongly disagreed with this statement with 8.3% participants agreeing with this statement. Most participants found the 'learn by doing' approach present in the experience to be helpful in learning locomotion techniques.

7.5 Summary

This chapter presents the study results, showcasing the outcomes obtained through thematic analysis. The identified codes and themes are systematically outlined, providing a comprehensive understanding of the data. Additionally, the Likert-style questions are thoroughly addressed, offering insights into participants' responses and perceptions in relation to the research objectives.

Chapter 8 Discussion

The following chapter will discuss and address the results collected throughout the study as well as compare them to the framework created in the study that was employed in the teaching tool. Secondly, the chapter will discuss the limitations faced by the study critically analysing aspects of the study that may have limitations and consequences on the results.

8.1 Results Analysis

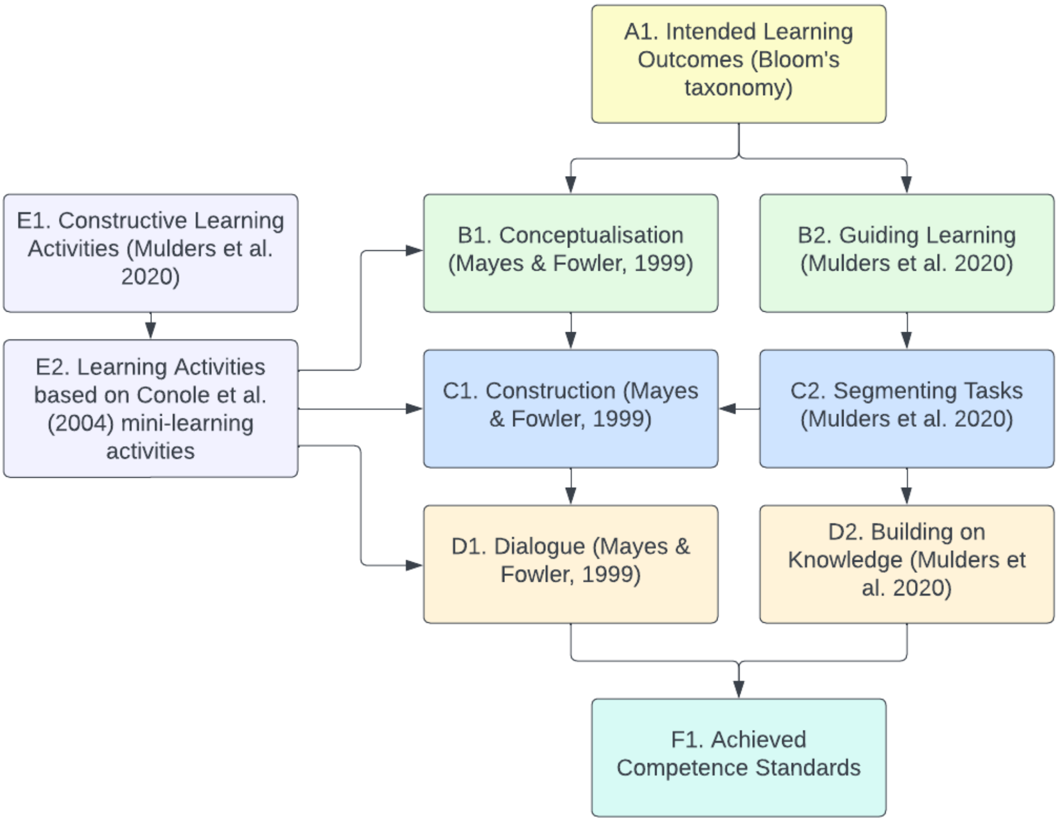

Figure 37 The diagram of the framework created for the study and used in the creation of the experience

The outcomes of this study have provided insight into participants' perception of learning VR locomotion techniques and their impact on users experience through VR itself. The results additionally provided insights into experiences using the created framework in the study in VR compared to ones without. However, any results discussed in this chapter should be criticized and interpreted with caution due to the limitations of the study. The limitations are discussed in the chapter with potential consequences to the results provided. This chapter will analyse the results received from the study against the framework that was created solely for the study.

The creation of the framework was one of the most crucial aspects of the research. The main research objective of the study focuses on evaluating the effectiveness of using this created framework-based approach in teaching VR using VR. The activities in the framework-based rooms used Constructive Learning Activities and Mini-Learning Activities denoted respectively as E1 and E2 (Figure 37). The created framework has led the creation of the codes and the data is discussed with the framework in mind. This research objective can be answered and addressed using the results discussed in this section. 10 out of 12 participants have shown a preference for the framework-based rooms that utilised the created framework. Participants tended to feel that the framework-based rooms increased their understanding of the material taught which pointed to participants building on their knowledge (D2, Figure 37) and potentially achieving higher competence standards (F1, Figure 37) sections of the created framework this may have also been due to the dialogue (D1, Figure 37) aspect of the framework which aims to help students to additionally build on their knowledge (D2, Figure 37). Participants felt that the learn by doing method, which is part of the construction (C1, Figure 37) segment of the created framework during the study, was beneficial to them. Participants enjoying the learn by doing approach is crucial as these results contribute to the understanding that the created framework is an effective and beneficial factor in VR teaching. The learn-by-doing approach is a part of the created framework in this study, coming from the construction phase of the framework denoted as C1 in the figure above (37). Participants reported very little feedback on the non-framework supported rooms, seemingly not finding them as memorable as the framework-based rooms. This may showcase that framework-based rooms were naturally more memorable and therefore participants may have found themselves building on knowledge (D2, Figure 37) more than usual. This is supported by participants stating that the interactive rooms were more useful to them and helped them understand the locomotion techniques more.

Participants have additionally felt that they have lost interest much faster with the non-framework-based rooms decreasing their learning experience showing that the framework was able to retain participants' interest longer. This may be due to the teaching theory that was utilised in the created framework which has shown to be beneficial for students. It is crucial to consider how effective VR experiences are without the use of a teaching framework, for example experiences that do not utilise a teaching framework may portray inaccurate benefits.

Participants have tended to not find the experience disorganised or unstructured, this question directly links with the framework as the question was asked only in relation to the framework-based room. The framework created in this study has two components, Guiding Learning (B2, Figure 37) and Segmenting Tasks (C2, Figure 37) these segments attempted to stop the experience from being disorganised or unstructured for participants. These results suggest that the framework was effective in creating an experience that did not feel disorganised for the user but instead felt structured. One of the reasons that multiple rooms were incorporated into the experience was due to the framework segment ‘Segmenting Tasks’ (C2, Figure 37) to segment the activities into multiple rooms. Multiple rooms was another aspect of the created framework belonging to the Segmenting Tasks (B2, Figure 37) and Guiding Learning segments (C2, Figure 37) that participants reported enjoying with one participant feeling that they provided for a more unique learning experience. While this feedback is not enough to understand the effect that segmenting tasks has had overall on participants due to the low number of data there may be a connection between multiple rooms and participants feeling that the experience was not disorganised or unstructured. As using multiple rooms was an aspect of segmenting learning it is reasonable to assume that this has contributed to the perception of structure and organisation participants have experienced.

Participants additionally enjoyed the self-paced experience; self-paced learning belongs to the guided learning (B2, Figure 37) category of the framework created in the study. Participants reported enjoying the ability to pause the audio with the ability to take the experience at their own pace. It is possible that participants having the opportunity to take the experience at their own pace beneficially contributes to their learning, as participants may be able to retain more information and find the experience positive overall. One participant reported enjoying the self-paced aspect of the conceptualisation stage (B1, Figure 37) where they were taught about locomotion techniques due to the ability to go back in the audio in case they have missed a segment of it. This supports and indicates that participants may have been able to retain more information and achieve higher competence standards (F1, Figure 37) through the ability to pause the experience when missing a segment.

The results of the study mostly suggest that learning VR locomotion techniques using VR is beneficial to students who are learning Game Design at higher education. Most participants reported positivity towards the experience and showcased an enjoyment of the content taught. Participants showcased more positive sentiment towards the experience rather than negative, with most participants complimenting the experience in some manner. Participants often found the experience to be more engaging and appreciated the learn by doing approach, many felt that it made more sense to them than the usual traditional classroom methods they have experienced. While some negative sentiment was present most of this was in relation to bugs and glitches found in the software rather than the experience. The findings suggest that participants may benefit from the use of VR on Game Design courses to learn VR theory. These results should be considered when considering ways of teaching VR to Game Design students at higher education.

11 out of 12 participants showcased a preference for VR over traditional classroom settings, this result contributes to the research objective focusing on comparing VR with traditional classroom settings for teaching VR methods. The results have shown that VR is the preferred method for teaching VR locomotion techniques in Game Design students, this data contributes to a clearer understanding of the potential advantages of VR compared to traditional classroom methods. Participants found the experience more engaging than a traditional classroom with some participants finding the experience to be much more immersive. Additionally, one participant described having ADHD and finding the experience to help them with focusing on the subject matter, this showcases another beneficial potential that VR may have on education. There may be a possibility that VR itself may be extra beneficial for students with ADHD or other conditions, however, more research is required into this area as the study did not focus on this and the study did not screen for medical conditions.

It is crucial to keep in mind that the reliability of this data may be impacted by the different traditional teaching methods that can be found in higher education. Each institute may have a different approach to teaching VR locomotion techniques, students who are taught with different approaches may have different perspectives on learning locomotion techniques using VR. For example, participants who are given different learning materials e.g. videos compared to other students who receive text based content may have different perspectives on the VR experience. However, overall the results found in this study show that there may be a preference for VR for VR based content that should be considered and explored further.

11 out of 12 participants have found the 'learn by doing' approach helpful, with 91.7% of participants strongly disagreeing with the statement '' I didn't find the 'learn by doing' approach helpful in learning locomotion techniques. This data suggests that using VR in VR teaching is beneficial overall by allowing participants to learn by doing. These results showcase a potential for using VR to teach VR to have stronger educational outcomes with may be beneficial to Game Designs' students learning. Secondly, these results further support the results of the study by showcasing the benefits of learning VR in VR. Participants have both enjoyed the VR experience over traditional classroom methods and have found the learn by doing approach exclusive to the VR experience itself to be helpful.

While the results demonstrated some negative sentiments towards the VR experience, the results additionally demonstrated a focus on bugs and glitches as the main area of negative sentiment. These results suggest that the negative sentiment held by participants is lesser to the experience itself as a concept but rather is focused on technological limitations which should be considered in future research. An experience with less technological issues such as bugs and glitches may alter participants' perception of the experience potentially resulting in less negative sentiments. This is crucial as it may be that VR itself as a tool can increase participants' learning outcomes, but this may be hindered by technological limitations. Additionally, it is crucial to consider this as a technological limitation in relation to creating an accessible VR experience. It may be that at this time no tool exists that can provide an accessible bug and glitch free experience while still proving to be accessible financially and use wise. Therefore, accessibility may be a current drawback in educational outcomes, with accessible tools often coming with technological limitations that may decrease participants' experience.

Some participants have found the experience confusing to navigate, with 3 participants agreeing that they had trouble with navigation. This is crucial in understanding how participants' experiences may have been affected by various factors of the experience. Participants that had no trouble with navigation may have found the experience more engaging and beneficial over participants who found the experience difficult to navigate. There may additionally be a correlation with participants who have had little VR experience prior to this experience and perceived problems with navigation. Some participants who have had little VR experience tended to report that they found the experience confusing due to this fact especially with complaints cantering on the controls of the experience. However, this must be explored further, and no definitive conclusion can be made from the results found due to the little number of participants who have never experienced VR before. More clear guidance and research into correct introduction for participants with little VR experience should be examined as this may drastically change the experience of participants in VR.

In conclusion, the chapter discussed and compared the data against the created framework used, describing how the framework affected participants' perceptions with the data collected during the study pointing to potential benefits of the framework. Most participants have found the framework to be beneficial in some manner with more participants than not commenting positively on it. No participants commented negatively on the framework showcasing that the framework was not detrimental to the experience that participants received. It is reasonable to believe that using a framework when teaching VR can be beneficial to the experience and potentially increasing learning outcomes, however more research into this is required due to the low sample size. The study provides new insight into the relationship between the usage of frameworks and teaching in VR, offering more information on the potential of VR as a teaching tool in higher education. These results should be taken into account when considering how frameworks impact teaching in VR. It is, however, beyond the scope of this study to accurately determine the full relationship between the usage of frameworks and VR due to the methodological limitations and low sample size.

8.2 Limitations

While the data contributes to a clearer understanding of VR's usage in teaching, it is crucial to address the limitations that may decrease the reliability of the data. The reliability of the data is firstly impacted by the low sample size, with only 12 participants it is unclear whether these results are applicable to a higher sample size. Additionally, all participants were from the same institute which further constrains the study. Participants from different institutes may have different perspectives and views on learning in VR.

Different teaching methods in classrooms may contribute to different opinions and views on VR itself and teaching within it, making it hard to determine how effective learning in VR is. It is beyond the scope of the study to accurately determine the true effectiveness of teaching VR in VR especially in relation to the framework. While the framework was created using research, it is unclear how effective this framework is itself compared to other frameworks. It is crucial to consider that other frameworks may be more or less beneficial in teaching participants in VR, therefore it is crucial to understand that the reliability of the data in this study is low and should only be discussed in relation to the created framework. The results from this study should not be used to assume that every framework will work effectively with participants.

Several participants reported having little VR experience, this in general limits the results. There is little understanding that can be taken from the data regarding the effects that the framework and learning through VR may have on individuals with little VR experience. It is additionally unclear the learning outcomes that were achieved by such individuals. It is possible that the lack of VR experience discounts the framework and reduces its effectiveness.

While most of the participants have enjoyed the experience, it is unclear how much more effective this experience was compared to traditional classroom methods. While participants have reported finding it more useful it is hard to determine how much. This is a crucial limitation as it addresses the need for more research into the exact differences between traditional classroom teaching and VR itself, especially with students learning in different traditional environments.

The use of qualitative questions in the study, while having benefits, has also caused limitations in the study. Not all participants discussed all segments of the framework in the open-ended questions provided to participants. For example, participants did not raise many points on the Dialogue segment of the framework, making it hard to understand and determine how beneficial this was for participants. Additionally, without all participants providing perspectives on every segment of the framework it is difficult to assess how much each aspect of the framework assisted participants and was enjoyed.

Bugs and Glitches additionally constrained the study. The presence of these technological issues poses the problem of 'how much did technological issues impact the experience?' it is reasonable to believe that the presence of these may have had a negative impact on participants. It is unclear how technological issues have impacted the experience, but participants did report finding the experience less immersive due to them. Additionally, this may impact the comparisons of the framework-based and non-framework-based rooms as participants who have experienced more technological difficulties in non-framework based rooms may have found them to be less effective than framework-based rooms for that reason rather than due to the lack of framework. Due to this the results cannot fully confirm just how much the framework-based rooms were more effective than non-framework based rooms and how much of this was affected by technological issues themselves.

An additional limitation of the study stems from the lack of participants' feedback on the discussion aspect of the framework. While discussion segments were implemented into the experience, very few participants provided any feedback on these areas. This shows that the framework's execution may not have been fully accurate and effective, this is crucial to address as it may be that the implementation of the framework overall was not fully reliable. It is beyond the scope of this study to determine how accurate the framework's execution was, with improvements having to be made in future implementation.

The study additionally suffered from it's pilot study nature. The study served as a pilot study with limited participants. Due to the lack of prior studies on this experience it is unclear whether the study was hindered by this. It is possible that the study was hindered by the lack of participants and prior feedback from additional Game Design students. Results would be more accurate with more Game Design students that could test the experience.

Due to the lack of data on the participants itself the study may suffer a further limitation, with a lack of information on the medical details of participants, their interests and even attendance on the course may limit the study's reliability. Participants with health conditions may need different adjustments that would have not been taken into account during this study, one participant reported having ADHD, which may have impacted their perception of the experience. Participants' interest is also crucial, as participants with a lesser interest in VR may have different attitudes towards the experience compared to students with higher interests in the content taught. Lastly, participants' attendance on the courses may impact their perception on the experience. Participants' with less attendance on the course may have different opinions on the experience when comparing the experience with traditional classroom methods.

The unstructured manner of a portion of the survey may additionally lower the reliability of the data. Some answers made by participants' may be misunderstood and misconstrued due to different backgrounds and understandings of language. It is crucial to keep this in mind when examining the results. Additionally, some participants may have understood questions differently than what was intended providing different answers than their true perceptions of the experience. For example, a participant may have misunderstood what was asked by 'learn by doing' feeling that the whole experience was a 'learn by doing' approach rather than the first two activities. Misunderstandings like this are crucial to consider when interpreting the reliability of the data.

Chapter 9 Conclusion

The following chapter aims to provide a conclusion to the study, describing the findings and analysing what was found in the study. Secondly the chapter aims to address the research objectives and questions in order to provide concise answers in relation to these. Lastly the conclusion will feature future work that should be undertaken in this field and reflections on the study.

This research has aimed to understand the effect that teaching VR's locomotion techniques in VR with a framework has on students. A study was conducted to understand participants' perception after trying out a framework-based VR experience.

A literature review was conducted to understand the accessibility of VR in education in order to assess accessible ways of teaching content in VR for higher education. Additionally, literature review was also conducted into understanding teaching frameworks in order to create an easy to use teaching framework for VR that can be used inter-disciplinarily by individuals without prior knowledge in the educational field. Lastly, locomotion techniques and their effects on user experience were additionally addressed in the literature review to effectively develop the tool for teaching locomotion techniques and their effects.

An accessible teaching framework was developed which was directly informed by the literature review, the teaching framework was then tested in a study with participants in a VR experience. The VR experience incorporated a Meta Quest 2 headset with the Mozilla Hubs software. The study aimed to understand participants' perception of the experience itself but also the experience compared to traditional classroom methods and none framework-based VR experiences teaching VR locomotion and its effects on user experience.

A quantitative and qualitative survey was carried out in order to understand the views of participants in the study. Most participants have reported preferring the VR experience over traditional classroom methods, reporting that they have found it more beneficial and educational. This was additionally the case for when participants compared the experience with a none framework VR experience which was also focused on teaching VR locomotion techniques and its effects on user experience.

Based on the quantitative and qualitative analysis undertaken in the Discussion chapter of the research, it can be concluded that using VR to teach VR is beneficial for students. The results additionally indicate that using frameworks in VR is highly beneficial to students and is more effective than using no frameworks in VR teaching. The research has identified accessible ways of teaching in VR education. Lastly, the research created an easy-to-use framework composed of teaching theory with the framework being tested through the conducted study.

9.1 Data Analysis

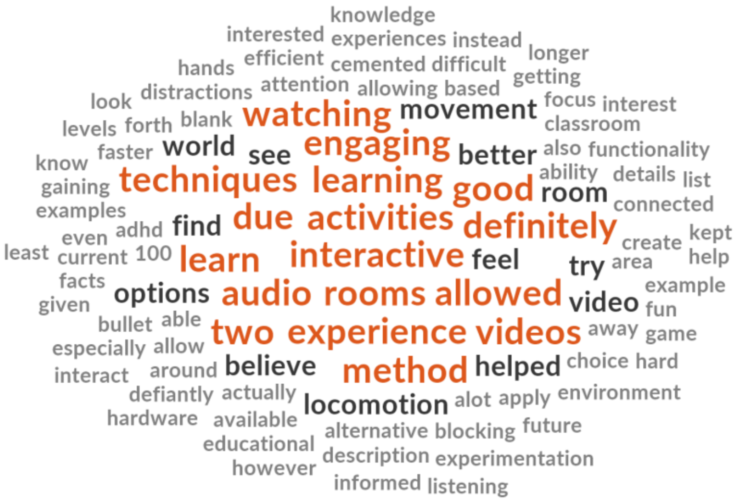

Figure 38 Word Cloud from Nvivo Software portraying 'preference for framework-based rooms' code

The data was analysed using thematic analysis. The Nvivo software was used to analyse the data and group codes into relevant themes. Firstly the data was read several times to create codes from participants' responses that related to the study. While creating the codes the research objectives and questions were read to ensure that the codes and themes of the research stay relevant.

The responses were then analysed in codes to find themes that related to the research at hand. The themes created were derived from the research objectives and questions, ensuring that all data discussed directly relates to the study. This was crucial in ensuring that the results discussion was relevant and connected to the study itself and therefore allowing the study to answer the objectives and questions of the research.

The usage of thematic analysis with the Nvivo software ensured that the data was handled in an academic manner with the most data accuracy. Using themes and codes allowing for the study to further understand participants' perception and understand how the results correlate to the study's research objectives and questions.

9.2 Research Objective Outcomes

The following section aims to discuss and analyse the research objectives undertaken and how they were fulfilled through the research.

Investigate the impact of locomotion techniques on user experience by conducting a literature review to inform the development of an effective teaching tool.

One of the research objectives focused on investigating the impact of locomotion techniques on user experience through a literature review to inform the development of the teaching tool. This was conducted through the literature review, the research has examined vital information on the effects of locomotion techniques on user experience. The research had looked at the different ways that locomotion techniques can influence users such as motion sickness, ease of use and tiredness amongst others. This helped in informing the teaching tool and providing an accurate educational experience to participants.

Identify and discuss existing frameworks for teaching in VR, utilizing the literature review to create an interdisciplinary, user-friendly teaching framework for locomotion techniques and their impact on user experience.

The thesis has discussed and identified existing frameworks for teaching VR through the literature review. The research has looked at the Meaningful iVR Learning Framework (Mulders et al. 2020) as well as Fowler's (2015) improved framework for teaching in Virtual Reality. The research analysed these frameworks and then applied them in order to create a new framework. The newly created framework was created to be user-friendly, easy to use and understand in interdisciplinary situations.

Assess the current accessibility of VR in education by analysing the teaching and research landscape through the literature review, aiming to determine the most accessible form of VR instruction.

The study has conducted a thorough literature review into the current accessibility of VR in education. Analysing and assessing the field. The study has presented multiple options for accessible teaching through VR such as the Google Cardboard, Meta Quest 2 and Google Daydream. The study has additionally analysed software that is accessible, easy to use and financially affordable, in order to asses the most accessible form of software for education. The study has showcased software such as the Mozilla Hubs and Spoke as appropriate software in accessible VR education.

Implement the developed teaching framework from the literature review to create a financially viable and easy-to-use teaching tool in VR, focusing on educating students about locomotion techniques and their impact on user experience.

The research has aimed to develop an accessible teaching tool in VR that focuses on teaching locomotion techniques and their impact on user experience through the use of a developed teaching framework. This was achieved in the research through the development of the tool supported by the literature review. The development of the tool was described in the Design Decisions chapter as well as Environment Execution showcasing the development. Additionally, the tool has incorporated the literature review in the development to ensure that the tool aligns with the research objectives. The tool was developed with the Meta Quest 2 and Mozilla hubs software which were identified as two accessible ways of developing in VR. Furthermore, the tool was developed in mind with the created framework. Each room in the experience was directly influenced by the framework with each activity and section having a direct link.

Evaluate the perception of the teaching framework using a qualitative and quantitative survey with participants to understand and assess the effects of the developed teaching tool on students.

The research objective of the study was to evaluate the perception of the framework itself. This was done through a qualitative and quantitative survey. Participants were asked to participate in a pilot study in which they took part in a short VR experience focused on teaching locomotion techniques and their impact on user experience. Participants were asked to go through several rooms in the experience, 3 rooms were based on the created framework with the last one not using a framework but teaching similar content. At the end of the experience participants were asked to fill out a survey. Participants reported greatly enjoying the hands-on experience that VR provided feeling that it makes much more sense to learn VR locomotion techniques and their effects in practice compared to on a screen. Participants additionally felt that they were able to understand better which locomotion techniques should be incorporated into their Game Design projects. Overall participants demonstrated positive sentiments towards learning VR locomotion techniques in VR showcasing potential in using VR to teach locomotion techniques. The study has achieved this research objective through the qualitative and quantitative survey undertaken.

Compare participant views on the teaching framework, experiences without a framework, and traditional classroom methods using a qualitative and quantitative survey for a clear assessment of the effects of the experience on Game Design students.

The study included a survey which has assessed participants' views on the experience compared to traditional classroom methods and experiences without using the framework but teaching the same content.

Participants found the VR experience highly beneficial compared to traditional classroom methods, feeling that they have gained more knowledge than in a classroom. Participants additionally found the experience much more engaging compared to traditional classroom methods. Lastly, participants have shown a preference for framework-based room over the no framework based room, showcasing the potential benefits of the framework. Based on these results it is reasonable to believe that the use of frameworks in VR has a beneficial effect on students. The results additionally showcase the benefits of using VR to teach VR. The results fulfil the research objective and additionally provide new insight into VR education as a whole.

9.3 Research Question

The following section aims to address the research question which has been driving the thesis and research objective. The section will aim to answer the research question.

What impact does teaching University Students Virtual Reality locomotion techniques in the system have compared to traditional teaching methods have on Game Design students?

The research addressed the impact of using VR in order to teach VR locomotion techniques in the system have on Game Design students compared to traditional classroom methods. Participants reported a higher enjoyment of learning with participants feeling that VR offers ways of learning that a typical traditional classroom cannot offer. The results have showcased that using VR in order to teach VR locomotion techniques is more effective than traditional classroom methods having a positive impact on Game Design students at higher education.

What effects does teaching Virtual Reality locomotion techniques with a framework in the system have on students specializing in game design at the university level?

The research has answered this question through the study conducted. The results demonstrate that using VR to teach VR locomotion techniques is highly beneficial for students. The study has demonstrated that the usage of the framework is beneficial for students with students feeling that they were able to understand the topic better and implement their knowledge in their Game Design projects. Additionally, students have felt that learning VR locomotion techniques in VR made much more sense providing them with more knowledge. The research demonstrated the effects that teaching Virtual Reality locomotion techniques in the system itself with the use of the framework has on University Students.

What effects does teaching University Students Virtual Reality locomotion techniques with a framework in the system have on Game Design students, in contrast to teaching the same techniques in the system without a framework?

The research has demonstrated the effects of teaching locomotion techniques in VR with a framework compared to teaching locomotion techniques in VR without a framework. A study was conducted in which participants underwent an experience presenting them both methods, one without and one with the framework.

After the experience participants were asked their opinions, asking them to directly compare the non-framework based rooms with the framework based rooms. Participants have expressed a much higher preference for framework-based room, finding them more beneficial. Participants have additionally enjoyed the hands-on experience offered by the framework and found the non-framework based rooms less engaging finding themselves to lose interest much quicker than with the framework based rooms. From the research using an educational framework in VR greatly increases the positive effects of the experience on participants.

It is important to consider that there is little research done into VR teaching frameworks, more research is needed into understanding the effects that different frameworks may have on students. While the study has shown that frameworks can be more beneficial than not using one, it is unclear if this applies to other frameworks. This issue is beyond the scope of this research and would require another study conducted.

9.4 Reflection

It would have been beneficial for the study to use more headsets and locomotion techniques. The study employed 2 locomotion techniques with the framework which limited our scope of understanding. Using more locomotion techniques would have provided additional insight into the framework's effects on Game Design students.

There was a significant number of participants who had never used a VR headset before. It would have been more beneficial for the study to compare the opinions and perspectives of participants who have prior VR experience compared to participants without. This would have provided a more clear insight into how teaching VR content in VR itself is perceived by participants. It may be that using VR to teach VR is more beneficial for participants with prior experience than without.

Lastly the study only had a sample size of 12 participants, the outcome of the study could be different if more participants were employed. The study would additionally benefit from participants from different higher institutions in order to compare how participants perceive the experience from different backgrounds.

9.5 Future Work

Future work is needed in this area due to the limited reliability of the results and limited research in teaching virtual reality concepts through virtual reality itself for game design students, especially with the use of frameworks. More research must be done into participants perception of frameworks in VR, with a focus on participants from different educational settings. This is especially the case for participants from different institutions with different ways of being taught Game Design, specifically VR. A more in depth analysis will allow for a clearer understanding of the actual effectiveness of VR for teaching VR.

Additionally, more research should be conducted into the potential differences between students' perceptions from different backgrounds, especially students with different medical conditions. Studies should further be conducted with more participant screening, checking for levels of interests and medical conditions to understand if adjustments must be made. More understanding into how medical conditions impact VR learning are necessary, especially comparing traditional teaching methods with VR for education for students with medical conditions such as ADHD. Research into this will contribute a clearer understanding into how VR affects students.

More studies must be conducted with a bigger sample size to provide a clearer understanding of teaching VR using VR. Bigger sample sizes will assist in gaining a clearer understanding of how the effects of VR for teaching VR.

Research should additionally be conducted with varied frameworks in order to understand if certain frameworks are more effective with others. More experimentation should additionally be done into understanding the essential aspects of teaching theory that may be implemented in the VR environment. Additionally, more research should be conducted into ensuring the implementation of the framework is accurate with more clear guidelines created to avoid unreliable data.

More research should be conducted with different equipment, especially in relation to the headset and software. It is crucial to understand if different headsets, equipment and software would alter participants' experience and learning outcomes. Other locomotion techniques should additionally be tested to further understand the differences and nuances in teaching locomotion techniques in VR.

Lastly it is crucial to conduct more research into reliable ways to measure learning outcomes in the VR teaching environment. While self-reported qualitative data can provide valuable and key insight it is unclear the strength of learning outcomes in this study. Additional studies into this area could provide more reliable ways of examining and understanding learning outcomes across different frameworks.

9.6 Summary

The study has demonstrated the positive impact that VR teaching can have on Game Design students when learning Virtual Reality content such as locomotion techniques. It also provided evidence on the benefits of using frameworks to teach in VR and their benefits compared to no framework use in VR. The study has also demonstrated that participants highly enjoyed the VR experience and preferred it over traditional learning methods.

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Appendix A – Survey Questions and Results

Survey Title: Understanding the impact of using Virtual Reality to teach Virtual Reality's locomotion techniques.

Purpose of the study:

The purpose of the study is to understand the impact of using Virtual Reality to teach Virtual Reality's locomotion techniques. The study seeks to compare traditional teaching methods with using Virtual Reality as a teaching tool in order to understand how topics about Virtual Reality can be taught in Virtual Reality. The information will help in advancing education in Virtual Reality.

The following questionnaire is anonymous. Please do not write your name or any other comments that will make you identifiable on the questionnaire. Through completing the questionnaire you are consenting to taking part in the research.

Procedures

In order to take part in the study you will be asked to complete a 15 minute experience in Virtual Reality Oculus Quest 2 at the University of Hull's Media Hub. This experience will guide you through an immersive experience teaching you about different locomotion techniques. During this experience you will be asked to use a video game controller and will be seated during the experience. When using a Virtual Reality headset there is a risk of motion sickness, we ask that if you feel motion sick at any time to please alert the researcher and end the experience immediately.

After taking part in the immersive experience, we ask that you complete the 10-15 minute questionnaire. These questions will focus on your opinion and views on the immersive experience, your responses will be used in a Masters Research Project cantered around using Virtual Reality as a teaching tool to teach Virtual Reality itself, these answers will inform the effectiveness of the using Virtual Reality for such teaching.

How much of your time will participation involve?

Participating in this study will require approximately 30 minutes of your time, encompassing the VR experience (15) and the subsequent questionnaire (10-15 minutes).

Will my participation remain confidential?

All data will be kept in a secure encrypted cloud-based server and will not contain any personal identifiable data. All data stored will be for the purposes outlined above.

The data collected will be used to understand the effectiveness of Virtual Reality in teaching Virtual Reality itself. The data will be included in a published thesis and may be published in a peer-reviewed journal, no personal identifiable data will be published. All data will be destroyed a year after the end of the project.

How can I withdraw from the study?

You are free to withdraw from the study at anytime during the survey period, incomplete surveys will not be used in the study.

What happens now?

If you are interested in participating in this study, please proceed and complete the consent form by picking an answer. Following this, you will receive further instructions. If you decide not to participate, kindly refrain from signing the form. Feel free to reach out to k.z.fedorczuk-2018@hull.ac.uk if you have any questions regarding the study.

Withdrawal:

You are welcome to withdraw from the study at any point to submitting the questionnaire. You can withdraw either by not completing the questionnaire or by not submitting the questionnaire.

Contact information:

For additional inquiries related to this study, please contact Kalina Fedorczuk at the University of Hull via k.z.fedorczuk-2018@hull.ac.uk.

Please tick the box if you consent to the study

- I agree and consent
- I do not consent

Please tick the box if you have completed the immersive experience

I have completed the experience

OPEN ENDED QUESTIONS:

Info for participants:

Please ask a researcher if any questions seem confusing, if you wish to withdraw from the study please do not complete the survey.

All questions unless stated otherwise apply to the first 3 rooms of the experience, NOT the last room with multiple breakout rooms.

1. In what ways do you think the virtual reality learning environment supported or hindered your learning compared to traditional classroom methods?

2. Do you think the virtual reality learning environment is a useful tool for teaching this Virtual

Reality locomotion? Why or why not?

3. Is there anything else you would like to share about your experience in the virtual reality learning environment?

4.Were there any challenges or difficulties you experienced in the virtual reality learning environment? If so, can you describe them?

5.In our VR immersive experience, which approach did you find more useful in teaching you about locomotion techniques: the rooms with audio and video materials found at the end of the experience or the two interactive activities allowing you to try the locomotion techniques yourself?

6.Why did you find this more useful? What made it better?

Likert Scale Questions

Please take a moment to complete the Likert scale questionnaire by indicating your level of agreement or disagreement with each statement. Utilize the provided scale, ranging from 'Strongly Disagree' to 'Strongly Agree,' to express your thoughts accurately. Your thoughtful responses are greatly appreciated and will contribute significantly to the survey's objectives.

1. I have found the experience to be disorganised or unstructured.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
☐	☐	☐	☐	☐

2. I have found the experience confusing to navigate.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
☐	☐	☐	☐	☐

3.I have found the activities useful and helpful in understanding locomotion techniques

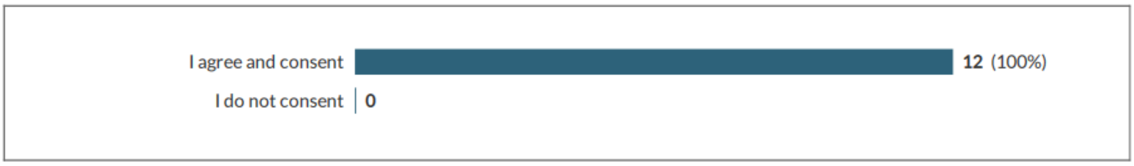
Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
☐	☐	☐	☐	☐

4.I didn't find the 'learn by doing' approach helpful in learning locomotion techniques

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
☐	☐	☐	☐	☐

Appendix B – Survey Results

Please tick the box if you consent to the study



Please tick the box if you have completed the immersive experience

In what ways do you think the virtual reality learning environment supported or hindered your learning compared to traditional classroom methods?

Showing all 12 responses Show less	
It was great to have a physical experience of what I was learning while learning it. However, sometimes I felt that minor bugs distracted from the immersion of the learning. Some scaling issues were also distracting as I felt the last few learning rooms were too tight.	1094732-1094714-115714955
I was abit distracting since I'm one of many people who are new to vr, so it was distracting, but after using it for awhile it would definitely be more engaging with things being shown directs instead of in a screen on your pc	1094732-1094714-115716359
Hindered due to not using how to use it, I had trouble with movement and knowing where I was, so I ended up concentrating on that more than a lot of the content.	1094732-1094714-115718275
I feel it supported it slightly as I could go through the experience at my own pace and watch the videos without constant need for pausing or going back.	1094732-1094714-115721978
it would allow work from home better which helps with accessibility they is just the startup cost that can be a lot for some.	1105366-1105348-117024933
Being educated on the virtual environment and its traversal methods WITHIN virtual reality helped me get a grasp on the actual effectiveness of each traversal method by letting me have hands-on experience.	1105366-1105348-117024711
Practical learning works for me - having never used Oculus learnt the basics	1105366-1105348-117024706
The virtual reality allowed for more varied teaching locations, as well as provide activities within a space. However, in a few locations, I became distracted with looking around areas and locations that were not intended to be seen, such as behind the image walls in the first room, and a broken wall in the third room	1105366-1105348-117027663
engaged in the world and learned more about layouts and how the player would interact with it	1105366-1105348-117024710
It allowed me to try out the ways of locomotion that was being taught, allowing me to gain a better understanding.	1105366-1105348-117030318
I think that virtual learning could be a great way to make learning more interactive and understandable for users	1105366-1105348-117030947
It was more interactive and engaging than traditional classroom methods	1105366-1105348-117031966

Do you think the virtual reality learning environment is a useful tool for teaching this Virtual Reality locomotion? Why or why not?

Showing all 12 responses Show less	
Yes definitely, it's great to have a practical example!	1094732-1094714-115714955
yeah, being able to learn them in real time was way better than say watching a video	1094732-1094714-115716359
I think with more refining and education, I'd recommend seeing if you can make the buttons more obvious in the controllers as with my cordination issues I didn't know which i was clicking most of the time.	1094732-1094714-115718275
I believe it is because it will show the user what can be done in the space with Virtual Reality and allows the user to see some different forms of delivery with real examples.	1094732-1094714-115721978
i really enjoyed it! it allowed me to try out new forms of movement as i am learning about them making me a lot more engaged then if i was just watching a video.	1105366-1105348-117024933
Definitely. It is one thing to be told that using a controller method to move around may feel awkward and possibly cause motion sickness, but entirely another to actually experience the movement methods hands on.	1105366-1105348-117024711
I do. It makes the most sense to learn in practice	1105366-1105348-117024706
I believe that using multiple rooms tailor made to the specific forms of locomotion allowed for a more unique learning experience, and allowed me to interact with the environment and teaching apparatus in a way that a normal teaching situation could not provide.	1105366-1105348-117027663
Yes it is because it help people that never tried it get a better understanding with it	1105366-1105348-117024710
i think it was very useful as it lets you experience it in real time	1105366-1105348-117030318
I do think so as you are using the technology while learning about how it is or could be used	1105366-1105348-117030947
Yes, because it allows the user to become used to the controls of virtual reality and offers a more fun and interactive experience	1105366-1105348-117031966

Is there anything else you would like to share about your experience in the virtual reality learning environment?

Showing all 11 responses Show less	
It was really useful for learning, I might have liked in the last few learning rooms to have more things to look at. Also some more guidance about where to go especially in the controller movement part. Also I think the left & right are mixed up in the controller movement explaination.	1094732-1094714-115714955
I wasn't able to break out when trying so that's good, it was also really easy to use	1094732-1094714-115716359
Dizzy.	1094732-1094714-115718275
To someone new to VR, I can imagine the experience being slightly disorienting. However, with previous VR experience, I did not struggle and the experience was enjoyable.	1094732-1094714-115721978
I enjoyed the audio that changed direction as you changed your head and being able to pause the audio incase you need a break so you don't have to sit through it again if you miss a part.	1105366-1105348-117024933
I'm pretty sure I did it wrong - From the initial control room I ended up in a futuristic tropical environment with no instruction and no way to move besides looking at a menu	1105366-1105348-117024706
The first room showed the method of changing scenes as pressing the A button, not the button on the front of the controller, there was a broken wall in the maze, and the audio got a lot quieter if you move a inch away from the spawn location	1105366-1105348-117027663
The sound was quiet and mostly in one side of the room rather than being evenly spread out. Forces the tester to listen to it without moving around properly.	1105366-1105348-117024710
I think it was very informative, and very fun which encouraged me to learn more	1105366-1105348-117030318
I think making virtual learning more interactive would keep the users attention for longer	1105366-1105348-117030947
N/A	1105366-1105348-117031966

Were there any challenges or difficulties you experienced in the virtual reality learning environment? If so, can you describe them?

Showing all 12 responses Show less	
I felt some minor motion sickness when using the controller method, to be expected with this method.	1094732-1094714-115714955
Due to the software having features put on by default such as the pen they were not accounted for, leading to them making my playthrough softlock, so accounting for stuff like this seems manditory to avoid people following suit	1094732-1094714-115716359
I broke the movement by accident then couldn't access the end rooms.	1094732-1094714-115718275
The only thing I could mention was the turning feature. It would rotate you in blocks that sometimes felt like I was out of position. In the end I just started to turn my head instead of using the joystick.	1094732-1094714-115721978
i am not a person who suffers from motion sickness but with the controller method i found myself feeling like i was falling over but still manageable	1105366-1105348-117024933
Some of the audio tracks were clipping into objects in the level. This wasn't an issue for me as I didn't need to rewind them and had access to the play button. I'm also uncertain if this was an issue unique to my headset or something to do with the hardware and speaker placement but the audio seemed to be stronger in the left ear	1105366-1105348-117024711
There was no instruction besides the first room and I had no idea where to go after learning the first set of controls - I thought this was poor	1105366-1105348-117024706
There was a problem initially with loading the learning environment, due to how the system was set up initially, I thought I was in the experience when in reality, I was not	1105366-1105348-117027663
In the final part when exiting the breakrooms the exist option wasn't working all the times.	1105366-1105348-117024710
I think the audio was fairly limiting as i wanted to listen to it all, however i had to be next to the sound block and some audio only played in my left ear (might be an issue with the headset not the game) this could be improved if the sound followed you through the area	1105366-1105348-117030318
I was sometimes unaware of what to do next but eventually I found my way to the next part of the experience	1105366-1105348-117030947
When I moved the position with the joystick I did start to feel slightly nauseous. This feeling subsided once I had stopped for a couple of seconds	1105366-1105348-117031966

In our VR immersive experience, which approach did you find more useful in teaching you about locomotion techniques: the rooms with audio and video materials found at the end of the experience or the two interactive activities allowing you to try the locomotion techniques yourself?

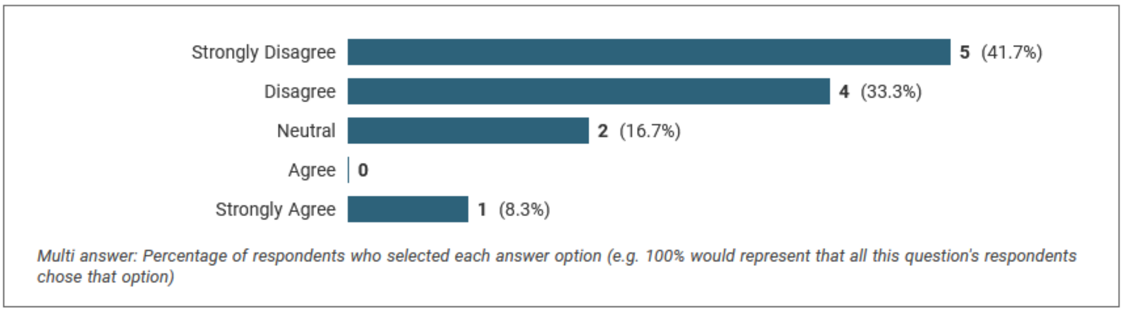
Showing all 12 responses Show less	
Definitely the two interactive activities allowing the trial of the locomotion techniques myself.	1094732-1094714-115714955
interactive 100%, I lost interest alot faster with the blank rooms with videos, so the interactive are definitely the way to go as otherwise why even be in vr, your still watching a video, at least that is how I see it	1094732-1094714-115716359
The audio didn't work so I'm not entirely sure, I had trouble getting in the rooms and they felt very small and I couldn't see all of the text at once on a wall.	1094732-1094714-115718275
While the rooms with audio and video were good, I believe the interactive rooms were better for learning. It will allow any user to see how it actually works when they apply themselves into the VR space.	1094732-1094714-115721978
defiantly the interactive levels!	1105366-1105348-117024933
In regards to options available on current soft/hardware, the rooms that you had to traverse with a given method were better at gaining the experience necessary to make an informed choice on which method you preferred or would use in your future game projects	1105366-1105348-117024711
I did not find the audio or video materials so I cannot answer this	1105366-1105348-117024706
In my opinion, I believe that the rooms with the interactive activities were more useful.	1105366-1105348-117027663
The interactive activities , especially with more focus on audio description rather than written.	1105366-1105348-117024710
definitely the interactive rooms	1105366-1105348-117030318
The two interactive activities kept me interested for longer which helped me understand more.	1105366-1105348-117030947
The two interactive activities which allowed me to try the locomotion techniques myself	1105366-1105348-117031966

Why did you find this more useful? What made it better?

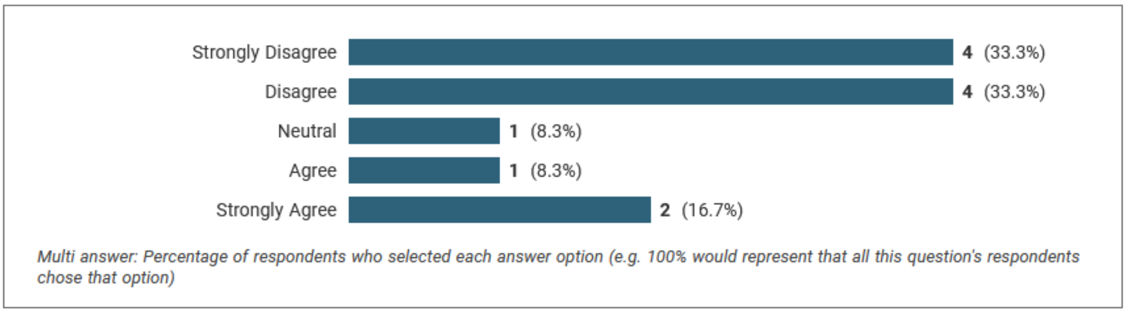
Showing all 12 responses Show less	
It made the learning feel more cemented having my own experience of it. For me I find normal classroom experiences difficult due to ADHD and so the room based learning was hard for me due to attention span, whereas the practical examples were very fun and engaging!	1094732-1094714-115714955
its more engaging due to the vr part since your can only interact with it when normally you can look around the room, your phone, so on so forth, it also proves to be more engaging with activities and blocking these distractions out	1094732-1094714-115716359
Again I think it needs refining, as I had trouble due to not knowing which buttons I was pressing, where I was going and such.	1094732-1094714-115718275
The functionality of VR is shown off more in the interactive sections and, overall, interactive learning has proven more efficient than watching videos/listening to audio.	1094732-1094714-115721978
They allowed me to learn about movement then try it out for myself! very memorable and i find myself taking away good knowledge on movement techniques.	1105366-1105348-117024933
Getting hands on experience is unparalleled. A mere bullet point list of facts and details about traversal methods can only help so much. It was however very good to know about alternative options that we couldn't experience in this VR world.	1105366-1105348-117024711
See above	1105366-1105348-117024706
they allowed for more experimentation, and showed the utility of each method.	1105366-1105348-117027663
Showing the controls from the start and helping new vr testers get a grip on what is it all about.	1105366-1105348-117024710
i was able to go through an area and learn as i went through instead of stationary watching example videos of what i could be doing	1105366-1105348-117030318
I think having the ability to create a whole educational environment in a moveable virtual world helped me learn and feel more connected to what I was learning	1105366-1105348-117030947
It allowed me to experience it at my own pace	1105366-1105348-117031966

Please take a moment to complete the Likert scale questionnaire by indicating your level of agreement or disagreement with each statement. Utilize the provided scale, ranging from 'Strongly Disagree' to 'Strongly Agree,' to express your thoughts accurately. Your thoughtful responses are greatly appreciated and will contribute significantly to the survey's objectives.

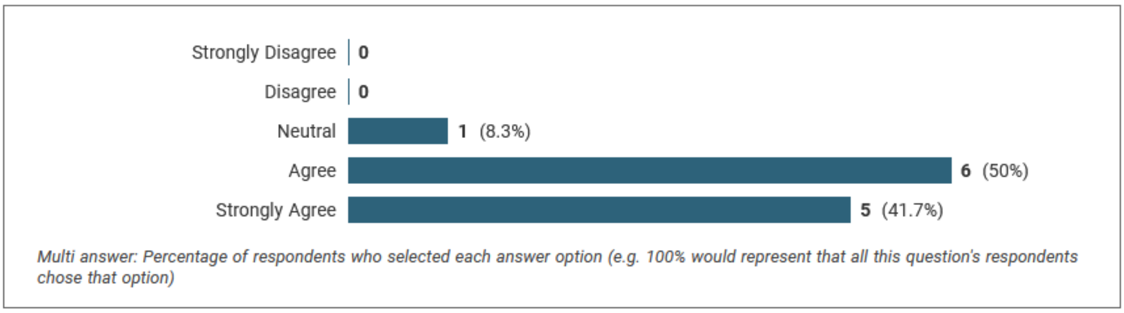
I have found the experience to be disorganised or unstructured.



I have found the experience confusing to navigate.



I have found the activities useful and helpful in understanding locomotion techniques



I didn't find the 'learn by doing' approach helpful in learning locomotion techniques